ORIGINAL ARTICLE

Simulation-based evaluation of emergency medicine residents' preparedness for toxic terrorism

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ABSTRACT

BACKGROUND: Toxic terrorism is a rare but potentially catastrophic threat that can result in mass casualties and overwhelm healthcare systems. Effective management of such incidents requires specialized clinical competencies and preparedness that may be underemphasized in standard emergency medicine training. This study aimed to assess emergency medicine residents' competencies in toxic terrorism preparedness and emergency medical management using a structured simulation-based examination.

METHODS: Emergency medicine residents working in the emergency departments of two tertiary university hospitals in Trabzon participated in a simulation-based clinical assessment. The examination comprised five realistic, fully immersive objective structured clinical examination (OSCE) stations designed to evaluate diagnostic decision-making and treatment planning in toxic terrorism scenarios. Each station was scored using standardized checklists developed by medical toxicologists. Factors associated with improved performance were also examined.

RESULTS: Although 33.3% of participants successfully passed the botulism scenario (Station 3), no participant successfully completed all five stations. The radiation exposure scenario (Station 2) was the most challenging. Higher performance was significantly associated with having more than 24 months of residency training, prior chemical, biological, radiological, and nuclear (CBRN) training, and previous exposure to simulation-based education.

CONCLUSION: These findings suggest that current training may not adequately prepare emergency medicine residents to manage toxic terrorism incidents. Incorporating standardized simulation-based assessments, such as OSCEs, into residency curricula may help identify training gaps and improve preparedness for low-frequency, high-impact events.

Keywords: Chemical, biological, radiological, and nuclear; emergency medicine; simulation; toxic terrorism; toxicology; training.

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INTRODUCTION

Toxic terrorism refers to the use of chemical, biological, radiological, or nuclear (CBRN) agents as threats or weapons to cause panic, illness, injury, and death within civilian populations.[1] Incidents of toxic terrorism involving CBRN agents have become an increasing global concern. Although toxic syndromes are most commonly associated with chemical agents, biological (e.g., anthrax), radiological (e.g., internal contamination), and nuclear (e.g., acute radiation syndrome) exposures can also result in distinct, life-threatening clinical conditions that require rapid recognition and emergency intervention. The use of chemical agents in modern warfare has been extensively documented. In Syria, between 2013 and 2020, at least 234 chemical attacks were recorded, resulting in more than 13,000 injuries and 3,400 deaths; 211 of these attacks involved chlorine gas alone or in combination with other agents.[2,3] The United Nations and independent human rights organizations have documented multiple sarin and chlorine attacks, most of which targeted civilian populations. In the context of the Russia–Ukraine war, battlefield reports and open-source intelligence have raised concerns regarding the use of riot-control agents and toxic industrial chemicals, such as chloropicrin, allegedly deployed in enclosed environments in violation of international law. Additionally, Russia has a documented history of using chemical agents in targeted assassinations, including the 2018 Novichok poisoning of former spy Sergei Skripal in the United Kingdom and the 2020 poisoning of opposition leader Alexei Navalny.[4] Recent intelligence reports have suggested that Russia may be preparing a chemical or radiological attack against Ukraine, accompanied by disinformation campaigns intended to justify such actions.[5] These developments underscore the global need for preparedness against CBRN terrorism incidents across emergency healthcare systems. Diagnostic uncertainty and limited experience in emergency management may delay the initiation of life-saving interventions and increase patient morbidity and mortality during toxic terrorism incidents.

The current emergency medicine residency curriculum includes limited content on toxic terrorism preparedness and medical management, and the extent of coverage varies across training programs.[6] Effective preparedness for toxic terrorism requires a multilayered approach involving national strategies, interregional coordination, and institutional planning. National frameworks establish policies, allocate resources, and ensure alignment with international conventions.[7] Interregional preparedness promotes standardized protocols, mutual aid agreements, and coordinated response capabilities across healthcare systems. At the hospital level, operational readiness depends on structured training programs, adequate personal protective equipment, established decontamination procedures, and regular disaster drills.[8-10] Within this framework, simulation-based Objective Structured Clinical Examinations (OSCEs) represent an important method for evaluating individual clinical competence. By recreating rare but high-consequence scenarios, OSCEs can identify knowledge gaps, assess decision-making under pressure, and determine whether institutional preparedness translates into effective frontline performance.[11–14] Previous studies have demonstrated that simulation-based OSCE performance correlates with subsequent clinical performance across several competency domains, including emergency decision-making and procedural skills.[13]

Assessing physicians' clinical skills in rare but high-risk scenarios, such as CBRN terrorism incidents, is essential for evaluating healthcare system readiness and identifying deficiencies in current management practices that can inform targeted training interventions. Accordingly, this study sought to address the following research questions:

1. What is the level of clinical competence among emergency medicine residents in managing toxic terrorism scenarios involving chemical, biological, radiological, or nuclear agents?

2. How do prior experiences, such as simulation-based training or exposure to real-world CBRN incidents, affect residents' performance in OSCE scenarios?

3. Which domains of clinical management (e.g., overall assessment and stabilization, decontamination, diagnostic activities, and specific treatment) represent the most significant gaps in performance?

The aim of this study was to assess the performance of emergency medicine residents in toxic terrorism scenarios using structured simulation-based OSCEs, with a particular focus on overall assessment and stabilization, decontamination, diagnostic activities, and specific treatment.

MATERIALS AND METHODS

Study Setting and Population

This was an observational study using a simulation-based assessment. Emergency medicine residents from the Karadeniz Technical University, Faculty of Medicine, Department of Emergency Medicine, and the Trabzon University, Faculty of Medicine, Department of Emergency Medicine participated in the study. The study was conducted at the Karadeniz Technical University Medical Education and Training Simulation Center (KTU-MEDSIM), which is equipped with the technology and resources necessary to provide authentic and clinically relevant simulation experiences.

The study protocol was approved by the Karadeniz Technical University Scientific Research Ethics Committee (Protocol No. 2021/216/ Date: 30.06.2021). The required sample size was calculated using G*Power version 3.1 software, assuming a medium effect size (f=0.25), an alpha level of 0.05, and a statistical power of 80% (1-β=0.80). Based on these parameters, the minimum required sample size was determined to be 42 participants. Both participating institutions followed the standard emergency medicine residency curriculum. In addition, the KTU, Department of Emergency Medicine offers a

structured toxicology training program consisting of monthly didactic lectures and daily bedside teaching delivered by a certified medical toxicologist. This training program is unique to KTU and is not available at the second participating institution. All emergency medicine residents actively working in either institution during the study period were eligible for inclusion, regardless of residency year. Residents who were on leave, rotating outside the emergency department, or unwilling to participate were excluded.

Study Design and Measurements

The simulation-based OSCE stations were developed by a panel of four experts. The research coordinator was an Associate Professor of Emergency Medicine with certification in simulation-based education and a PhD in toxicology. One researcher contributed to scenario development through an extensive literature review. Two additional medical educators with doctoral-level training and expertise in simulation-based education participated in the development process. One author had completed a one-year fellowship in medical education, while the other served as Co-Director of the KTU-MEDSİM and held a master's degree in medical education.

Development of OSCE Scenarios

The medical toxicologist served as the principal investigator and drafted the initial scenario framework. As this study was conducted as part of an emergency medicine residency dissertation, a comprehensive literature review was performed during the planning phase. Based on this review, a blueprint was developed to define the key topics and competencies to be assessed. Medical educators contributed to scenario development during the item-writing phase to ensure the clarity, relevance, and educational validity of the content. The researchers responsible for scenario development met repeatedly to refine and finalize the scenarios. Subsequently, three independent experts reviewed the scenarios and provided feedback to enhance their content validity and overall quality.

The OSCE consisted of five simulation-based stations: one utilizing a high-fidelity computerized manikin, two employing standardized patients, and two video-based scenarios. In the first three stations, residents were observed through live video and audio feeds from behind a one-way mirror, and their performance was evaluated across the management domains presented in Table 3 (recognition/diagnosis, PPE selection and decontamination, supportive treatment, and specific treatment). For the two video-based stations, participants viewed prerecorded footage and provided written responses. Developed by the research team, these scenarios depicted television news coverage of large-scale toxic incidents that were too complex to recreate within a single simulation station. The video scenarios were designed to convey the scale and severity of toxic agent attacks and to evaluate participants' management strategies in response to chemical terrorism incidents. To establish content validity, each scenario was reviewed by three independent experts.

Assessment forms for each scenario were developed based on the literature and expert consensus. These forms were subsequently reviewed by three independent experts, and revisions were made accordingly. The final assessment forms were completed in the simulation center control room by a team consisting of one medical toxicologist and five emergency medicine faculty members, all of whom had received training in simulation-based education.

Each station lasted 8 minutes, followed by a 2-minute transition period. These timings were established through pilot testing with residents who did not participate in the study. Entry and exit times were signaled by an audible buzzer. Two days before the assessment, all participants attended a standardized orientation session that included a video explaining station procedures and the capabilities of the high-fidelity computerized manikin.

No preparatory lectures, training sessions, or educational materials were provided before the OSCE because the objective was to assess baseline competence rather than evaluate an educational intervention. The only preparation permitted was a standardized orientation video describing the OSCE format, which was provided equally to all participants. This approach was intended to ensure a uniform level of familiarity with the examination process while minimizing the influence of external educational interventions. Factors potentially associated with performance included prior training in CBRN incidents, previous participation in simulation-based training, duration of residency training (>24 months), gender, and toxicology-related educational experiences. Potential confounding factors included baseline clinical competence, familiarity with similar scenarios, examination-related stress, and variability in the perceived realism of the simulations.

Although a formal interrater calibration session was not conducted before the study, all raters used standardized assessment checklists developed by experts in toxicology and simulation-based education. Participant performance was evaluated based on predefined critical actions ("golden steps") for each station. Any uncertainty or disagreement in ratings was resolved through post hoc review of video recordings and consensus discussion among the evaluators. This approach was intended to enhance rating consistency despite the absence of formal calibration.

This study was reported in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for cross-sectional studies.[15]

Simulation-Based OSCE Design

The simulation-based OSCE was conducted using a high-fidelity computerized manikin (Advanced HAL S3201; Gaumard Scientific, Miami, FL, USA) and standardized patients. A standardized patient is a trained actor who consistently portrays a predefined clinical role according to a scenario developed by subject-matter experts and course coordinators.[16]

A detailed summary of each station, including the scenario content, competencies assessed, and expected critical actions, is presented in Table 1. Photographic documentation of station setups is provided in Figure 1. The scenarios were specifically designed to assess residents' competencies in overall assessment and stabilization, decontamination, diagnostic activities, and specific treatment interventions.

All scenarios were designed to present a moderate level of clinical and cognitive difficulty consistent with the expected competencies of second-year and more senior emergency medicine residents. Scenario complexity was not modified according to training level. All participants received identical case content, event sequences, and decision-making requirements to ensure standardized assessment conditions across varying levels of experience. A faculty member from the Department of Emergency Medicine served as evaluator at each station. Video recordings were reviewed when necessary to verify or clarify performance assessments.

Data Collection

The study utilized a simulation-based OSCE that was reviewed and validated by three independent experts to assess clinical decision-making and medical management skills.



Figure 1. Simulation-based stations included in the study.

Table 1. Simulation-based OSCE scenarios for toxic terrorism preparedness

Station	Scenario description	Simulation modality	Key competencies assessed	Critical actions ("golden steps")
1	Organophosphate poisoning following exposure to an unknown liquid at a bus stop	High-fidelity manikin	Personal protective equipment (PPE) selection, toxidrome recognition, antidote administration	• Select appropriate PPE • Initiate patient decontamination • Recognize the cholinergic toxidrome • Administer atropine and an oxime antidote
2	Internal contamination following ingestion of radioactive material	Hybrid simulation (manikin + standardized patient [SP])	Decontamination, radiation emergency recognition, supportive management	• Select appropriate PPE • Recognize internal radioactive contamination • Initiate decontamination procedures • Establish the diagnosis and initiate appropriate treatment
3	Botulism presenting with ptosis and dysphagia following a shared meal	Standardized patient	Diagnostic reasoning, treatment initiation	• Recognize botulism • Request appropriate diagnostic tests • Initiate botulinum antitoxin therapy
4	Sulfur mustard exposure during a mass-casualty incident	Video-based scenario	Recognition of visual clinical findings, protective measures, symptomatic management	• Identify characteristic dermatologic findings • Initiate symptomatic treatment • Implement appropriate protective measures
5	Cyanide poisoning following an indoor explosion	Video-based scenario	Cyanide toxidrome recognition, antidote administration	• Recognize cyanide poisoning • Administer hydroxocobalamin • Initiate oxygen therapy

Assessment forms were developed based on published literature and expert consensus and were intended to evaluate both general professional competencies and scenario-specific clinical skills. Each station was evaluated using a predefined checklist developed by medical toxicologists. These checklists consisted of scenario-specific critical actions ("golden steps") considered essential for successful patient management. Participant performance at each station was classified into one of three categories: "Competent," "Partial competence," or "Failure." A participant was classified as "Competent" only if all golden steps were completed adequately. Performance was classified as "Partial Competence" if at least one critical step was partially completed or performed suboptimally. Performance was classified as "Failure" if critical actions were omitted or performed incorrectly.

For statistical analyses, "Partial Competence" and "Failure" were combined into a single category. No cumulative score was calculated across stations. Instead, performance was evaluated at the station level using a binary pass/fail framework. The decision to dichotomize performance ratings into a binary pass/fail classification was made a priori by the research team. This approach was intended to reflect the realities of high-stakes toxicological emergencies, in which the omission of a single critical action may result in adverse patient outcomes.

Because the study was designed as an assessment rather than an educational intervention, no real-time or post-scenario feedback was provided during the OSCE. To maintain standardization and minimize bias, facilitators did not offer guidance, commentary, or corrective feedback during the examination. Following completion of the study and data collection, all participants were offered the opportunity to review their performance and receive individualized formative feedback during one-on-one debriefing sessions.

Participants also completed written evaluations of their examination experience for internal quality improvement purposes; however, these data were not included in the study analyses.

Data Analysis

All statistical analyses were performed using SPSS version

Table 2. Participant characteristics

Variable	n=48	%
Gender		
Female	16	33.3
Male	32	66.7
Age group (years)		
20–24	1 / 1	2.1
25–29	36	75.0
30–35	10	20.8
36–41	1 / 1	2.1
Institution type		
Institution with a Medical Toxicology Unit	34	70.8
Institution without a Medical Toxicology Unit	14	29.2
Duration of residency training		
≤24 months	28	58.3
>24 months	20	41.7
Previous CBRN training		
Yes	17	35.4
No	31	64.6
Time since most recent CBRN training		
1 year	2	4.2
2 years	13	27.1
3 years	2	4.2
No previous CBRN training	31	64.6
Previous CBRN case management experience		
Yes	10	20.8
No	38	79.2
Previous simulation-based training experience		
Yes	24	50.0
No	24	50.0
Previous simulation-based CBRN training experience		
Yes	5	10.4
No	43	89.6
Performance by OSCE station	Competent	Not competent
Station 1: Organophosphate poisoning	2 (4.2)	46 (95.8)
Station 2: Internal radioactive (cesium) contamination	-	48 (100.0)
Station 3: Botulism poisoning	16 (33.3)	32 (66.7)
Station 4: Sulfur mustard exposure	13 (21.7)	35 (72.9)
Station 5: Cyanide poisoning	4 (8.3)	44 (91.7)
Number of stations at which participants achieved competence	n	%
None	28	58.3
1 station	9	18.8
2 stations	7	14.6
3 stations	4	8.3

Table 3. Participant performance across medical management domains by OSCE station

Station 1	Competent	Partial competence	Failure
Recognition of cholinergic toxidrome	30 (62.5)	-	18 (37.5)
PPE selection and decontamination	23 (47.9)	17 (35.4)	8 (16.7)
Supportive treatment	33 (68.8)	12 (25.0)	3 (6.3)
Specific treatment	2 (4.2)	11 (22.9)	35 (72.9)
Station 2			
Recognition of acute radiation syndrome	8 (16.7)	-	40 (83.3)
PPE selection and decontamination	3 (6.3)	1 (2.1)	44 (91.7)
Supportive treatment	9 (18.8)	1 (2.1)	38 (79.2)
Specific treatment	1 (2.1)	-	47 (97.9)
Station 3			
Recognition of botulism	30 (62.5)	-	18 (37.5)
Supportive treatment	40 (83.3)	8 (16.7)	-
Specific treatment	20 (41.7)	11 (22.9)	17 (35.4)
Station 4			
Recognition of sulfur mustard toxicity	15 (31.3)	-	33 (68.7)
PPE selection and decontamination	28 (58.3)	3 (6.3)	17 (35.4)
Supportive treatment	42 (87.5)	3 (6.3)	3 (6.3)
Specific treatment	28 (58.3)	3 (6.3)	17 (35.4)
Station 5			
Recognition of cyanide poisoning	8 (16.7)	-	40 (83.3)
Supportive treatment	39 (81.3)	9 (18.8)	-
Specific treatment	5 (10.4)	2 (4.2)	41 (85.4)

17 (35.4%) had previously received CBRN training, and 10 (20.8%) had managed at least one CBRN-related case. Table 2 also summarizes the number of stations at which residents achieved a competent performance. The highest success rate was observed at Station 3 (botulism), where 16 participants (33.3%) achieved competence. In contrast, Station 2 (radiation) was the most challenging scenario, with no participant achieving competence. Overall, 28 participants (58.3%) did not achieve competence at any station, whereas nine participants (18.8%) achieved competence at one station. No participant achieved competence across all five stations.

The numbers and proportions of participants rated as competent according to station and assessment domain are presented in Table 3. The highest rates of diagnostic success were observed at Stations 1 and 3, where 62.5% of participants correctly established the diagnosis. The highest rate of success in specific treatment was observed at Station 4 (58.3%), followed by Station 3 (41.7%). The lowest rate of success in supportive treatment was observed at Station 2, where only 18.8% of participants performed adequately. When participant characteristics were compared with performance at Station 1, residents who had previously managed a CBRN-related case were significantly more likely to achieve competence (p=0.040). No significant associations were identified for any other participant characteristics (p>0.05). Analysis of factors associated with performance at Station 3 demonstrated that participants aged 30 years or older and those with more than 24 months of residency training were significantly more likely to achieve competence (p=0.027 and p=0.003, respectively). Furthermore, residents who had received simulation-based training and simulation-based CBRN training achieved significantly higher success rates at this station (p=0.006 and p=0.037, respectively). For Station 4, residents who had received CBRN training, previously managed a CBRN-related case, or participated in simulation-based training demonstrated significantly higher success rates than their counterparts (p=0.006, p=0.016, and p=0.001, respectively).

The associations between participant characteristics and achieving competence in at least one station are presented in Table 4. Residents with more than 24 months of training, as well as those with prior CBRN training and simulation-based training experience, were significantly more likely to achieve competence in at least one station (Table 4).

Table 4. Association between participant characteristics and OSCE performance

	Competent in ≥1 station n=20 (41.7)	Not competent in any station n=28 (58.3)	p
Institution type			
Institution with a Medical Toxicology Unit	17 (50.0)	17 (50.0)	0.130
Institution without a Medical Toxicology Unit	3 (21.4)	11 (78.6)	
Duration of residency training			
≤24 months	5 (17.9)	23 (82.1)	0.001
>24 months	15 (75.0)	5 (25.0)	
Previous CBRN training			
Yes	12 (70.6)	5 (29.4)	0.007
No	8 (25.8)	23 (74.2)	
Previous CBRN case management experience			
Yes	7 (70.0)	3 (30.0)	0.070
No	13 (34.2)	25 (65.8)	
Previous simulation-based training experience			
Yes	16 (66.7)	8 (33.3)	0.001
No	4 (16.7)	20 (83.3)	

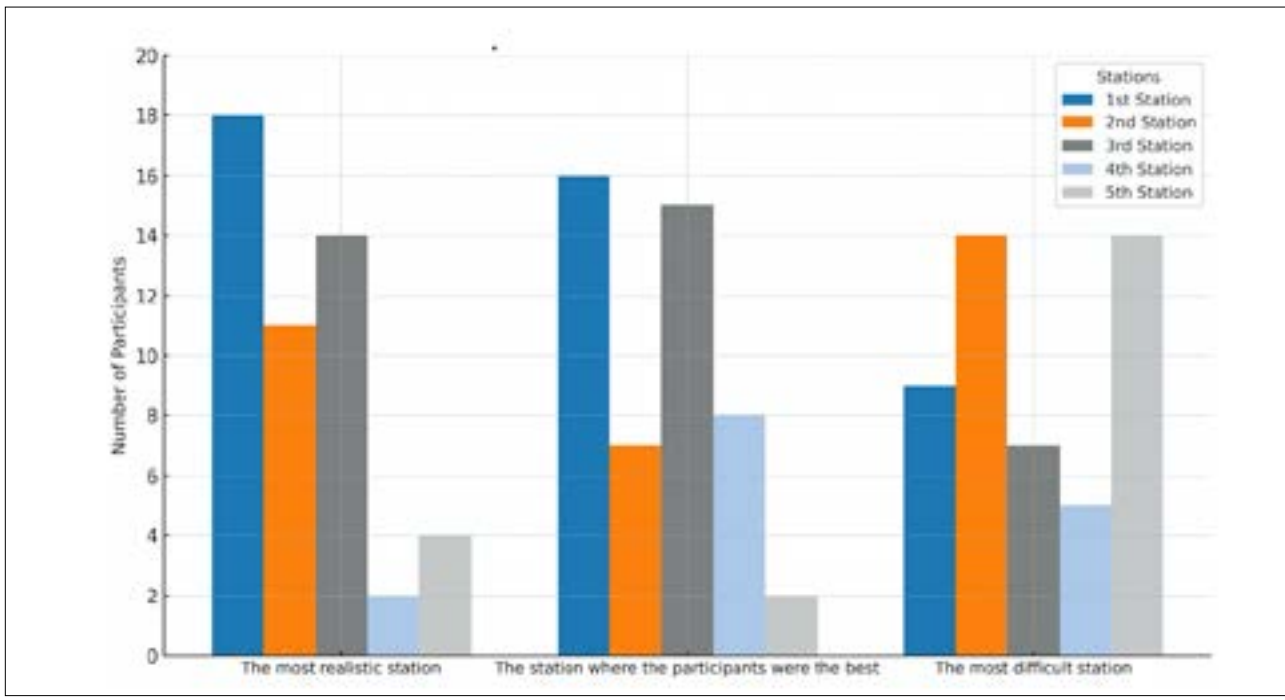


Figure 2. Participants' evaluations of the stations.

Participants were also asked to evaluate the realism and difficulty of the stations. Station 1 was rated as the most realistic scenario by 18 participants (37.5%), followed by Station 3 (29.2%) and Station 2 (22.9%). Participants most frequently reported feeling most successful in Station 1 (n=16, 33.3%) and Station 3 (n=15, 31.3%). Stations 2 and 5 were identified as the most difficult scenarios by 14 participants (29.2%) each (Fig. 2).

DISCUSSION

In this study, emergency medicine residents' clinical competencies in managing toxic terrorism scenarios were evaluated using a simulation-based OSCE. The results revealed that a substantial proportion of participants were unable to demonstrate adequate performance across critical domains, including overall stabilization, diagnosis, decontamination, and specific treatment. These findings suggest important gaps in toxic terrorism preparedness among emergency medicine residents and underscore the need for standardized, reproducible educational modules addressing CBRN incidents within emergency medicine residency curricula.

In the present study, residents with more than 24 months of training, prior CBRN education, and previous simulation-based training were significantly more likely to achieve competence in at least one OSCE station. Ryan et al.[17] reported that mean examination scores assessing medical knowledge and overall clinical competence among 59 emergency medicine residents increased significantly with advancing years of residency training. Our findings are consistent with previous evidence demonstrating that clinical knowledge and performance improve with increasing training experience. Dönmez [18] reported that 61.8% (n=268) of emergency medicine providers had not received any formal CBRN training. Similarly, Stevens et al.,[19] evaluated the perceived preparedness of 663 healthcare workers to respond to CBRN incidents and found significantly higher readiness scores among those who had received recent CBRN training. Kako et al.[12] demonstrated that simulation-based CBRN training can improve healthcare professionals' knowledge and preparedness for emergency response. In the present study, 31 residents (64.6%) had never received formal CBRN training, and prior CBRN training was significantly associated with higher proficiency rates. Compared with the existing literature, the relatively low proficiency rates observed in our study may reflect several educational deficiencies, including limited emphasis on CBRN terrorism within standard emergency medicine curricula, insufficient use of simulation-based training for high-risk and low-frequency scenarios, and the rarity of real-world CBRN exposures during residency training. Previous studies have shown that structured and repeated educational interventions—including realistic simulations, disaster drills, and scenario-based exercises—can substantially improve preparedness and performance in managing such events. Our findings further support the integration of standardized toxic terrorism and CBRN preparedness modules into emergency medicine residency programs.

Numerous studies have demonstrated the effectiveness of simulation-based CBRN training. In this study, participants rated the organophosphate poisoning station as the most realistic scenario; however, it was also associated with one of the highest failure rates. Errors involving critical interventions, such as the administration of atropine, suggest deficiencies in both practical skills and theoretical knowledge. Similarly, Eason et al.[20] found that sarin gas simulation exercises effectively improved healthcare workers' administrative and clinical competencies. A pilot study by Subbarao et al.,[21] utilizing both manikin-based and video-based simulations, demonstrated significant improvements in participants' knowledge following training. Furthermore, a virtual reality–based educational program that included practical decontamination procedures for radiation-contaminated patients provided substantial learning benefits through opportunities for individualized practice.[22] Collectively, these findings highlight the importance of practical and modular training approaches to reduce performance deficiencies in complex toxicological emergencies.

Among the five stations, the radiation exposure scenario (Station 2) was perceived, together with the cyanide scenario (Station 5), as the most difficult by participants. This finding is consistent with previous literature highlighting the complexity of radiation-related emergencies and the limited training opportunities available in this area. Ebeling et al.[23] reported that only 25% of participants, including 22 emergency medicine residents and one pharmacy resident, correctly diagnosed acute radiation syndrome (ARS) in a highly realistic simulation without explicit warning cues. Similarly, Sheikh et al.[24] found that only 37% of emergency medicine residents had received radiation-related training within the previous five years, suggesting that inadequate training negatively affects diagnostic and intervention competence. Together, these findings emphasize the need to increase awareness of radiation emergencies, strengthen diagnostic skills, and implement targeted educational strategies to improve preparedness.

Decontamination practices were also evaluated in this study. Although most participants recognized the need for decontamination, deficiencies in the selection and use of appropriate personal protective equipment (PPE) were common. In a survey conducted by Szarpak et al.,[25] only 26.1% of 510 physicians, nurses, and paramedics reported adequate knowledge of patient decontamination procedures. Consistent with these findings, cross-sectional studies of prehospital healthcare workers have identified significant readiness gaps and emphasized the need for additional training in decontamination procedures.[26,27] While participants in our study generally recognized the importance of decontamination, many failed to select appropriate PPE to protect themselves, highlighting a critical area for educational improvement.

Participants who achieved competence in at least one OSCE station were significantly more likely to have previous experience with simulation-based training. Approximately half of the residents had participated in such training, and these individuals demonstrated significantly higher proficiency rates. This finding reinforces the value of simulation-based education not only as a teaching modality but also as a reliable method for assessing clinical competence. Chen et al.[28] evaluated 68 emergency medicine residents using written examinations, oral assessments, and immersive simulation scenarios across

eight training periods. Similarly, Liu et al.[29] demonstrated that immersive simulation training was associated with superior end-of-training examination performance among nine emergency medicine residents. In rare but high-consequence toxicological scenarios, simulation within a structured and standardized OSCE framework offers distinct advantages because it evaluates clinical reasoning, decision-making, and procedural performance beyond simple knowledge recall.[30]

This study also has important implications for medical educators and emergency preparedness planners. First, our findings demonstrate that simulation-based OSCEs can effectively identify deficiencies in CBRN preparedness among emergency medicine residents, particularly in settings where direct clinical exposure is limited. Second, the combination of immersive simulation and video-based scenarios provided a cost-effective and scalable approach for evaluating core clinical competencies. Importantly, residents with prior simulation experience or formal toxicology training performed significantly better, supporting the integration of structured and repetitive simulation-based learning experiences into residency curricula. These findings align with recent recommendations advocating competency-based disaster education and support the use of modular, video-based training and assessment approaches.[31–33] Educational leaders and policymakers in comparable healthcare systems may consider adopting similar approaches to enhance preparedness for toxic terrorism, a rare but potentially devastating public health threat.

A review of the literature did not identify any previous studies evaluating the clinical competencies of emergency medicine physicians in the diagnosis and management of toxic terrorism incidents using a structured simulation-based assessment. Consequently, this study contributes to the literature by developing and applying a simulation-based clinical skills assessment focused on toxic terrorism preparedness.

Limitations

This study has several limitations. First, although the five scenarios were designed to represent key CBRN terrorism situations, they do not encompass the full spectrum of potential clinical presentations. A larger and more diverse scenario pool would improve generalizability. Second, the assessments were conducted on consecutive days to minimize information sharing among participants; however, informal communication and discussion of scenario content among residents could not be completely prevented. Third, although emergency medicine residency curricula are theoretically standardized across institutions in Türkiye, differences in local implementation and toxicology exposure may have influenced participant performance. Fourth, senior residents are more likely to encounter and manage CBRN-related incidents in clinical practice, which may limit the applicability of the findings to junior residents. Fifth, although the study sought to compare residents exposed to simulation-based education with those receiving structured toxicology training, only one participating institution offered formal toxicology rotations, limiting the strength of these comparisons. Sixth, the study was conducted at only two emergency medicine residency programs in Türkiye, which may limit the international generalizability of the findings. Seventh, the assessment instrument was not pilot tested before implementation. Although the scenarios and assessment forms underwent expert review, the absence of pilot testing limits the extent of formal validation. Finally, this study employed a cross-sectional design and assessed participants at a single time point; therefore, long-term knowledge retention and the effects of subsequent educational interventions could not be evaluated.

Although the simulation-based findings provide valuable insights into residents' preparedness for toxic terrorism incidents, their direct applicability to real-world clinical performance remains uncertain. Simulation environments cannot fully replicate the complexity of actual clinical practice, including patient interactions and environmental pressures. Future studies should examine the relationship between simulation-based performance and real-world clinical outcomes.

CONCLUSION

This study developed and implemented a standardized simulation-based assessment to evaluate emergency medicine residents' clinical competencies in the management of toxic terrorism incidents. The findings of this study highlight the need for a standardized core curriculum addressing CBRN and toxic terrorism preparedness within emergency medicine residency programs. Regular, competency-based training interventions should be incorporated to ensure that residents acquire the necessary competencies. Standardized, reproducible simulation-based assessments should be routinely incorporated into residency training to evaluate and reinforce preparedness for toxic terrorism, a rare but potentially high-consequence public health threat.

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Ethics Committee Approval: The study protocol was approved by the Karadeniz Technical University Scientific Research Ethics Committee (Date: 30.06.2021, Decision No: 2021/216).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Acil tıp asistanlarının toksik terörizme hazırlıklı olma durumunun simülasyon tabanlı değerlendirilmesi

AMAÇ: Toksik terörizm, nadir görülmesine rağmen kitlesel yaralanmalara ve sağlık sistemlerinin hızla kapasitesini aşmasına neden olabilecek yıkıcı bir tehdit oluşturmaktadır. Bu tür olayların yönetimi, standart acil tıp eğitiminde genellikle yeterince vurgulanmayan özel klinik beceriler ve hazırlık gerektirir. Bu çalışma, yapılandırılmış simülasyon temelli bir sınav aracılığıyla acil tıp asistanlarının toksik terörizme hazırlık ve acil tıbbi yönetim konusundaki klinik yeterliliklerini değerlendirmeyi amaçlamıştır.
GEREÇ VE YÖNTEM: Trabzon'daki iki üçüncü basamak üniversite hastanesinin acil tıp kliniklerinde görev yapan acil tıp asistanları simülasyon temelli klinik değerlendirmeye katılmıştır. Sınav, toksik terörizm senaryolarında tanısal karar verme ve tedavi planlamasını ölçmek üzere tasarlanmış, gerçekçi ve tamamen immersif beş istasyondan oluşan bir nesnel yapılandırılmış klinik sınav formatındaydı. Her istasyon, medikal toksikologlar tarafından geliştirilen standartlaştırılmış kontrol listeleri kullanılarak puanlanmıştır. Ayrıca performansı artıran faktörler de incelenmiştir.
BULGULAR: Katılımcıların %33.3'ü botulizm senaryosunu (İstasyon 3) başarıyla tamamlamış olsa da hiçbir katılımcı beş istasyonun tamamını geçememiştir. En zorlanan istasyon radyasyon maruziyeti senaryosu (İstasyon 2) olmuştur. Daha iyi performans, 24 aydan uzun asistanlık deneyimi, önceden alınmış kimyasal, biyolojik, radyolojik ve nükleer (KBRN) eğitim ve daha önce simülasyon temelli eğitime katılmış olmak ile anlamlı olarak ilişkili bulunmuştur.
SONUÇ: Bulgular, mevcut eğitimin acil tıp asistanlarını toksik terörizm senaryolarını yönetmek için yeterince hazırlamadığını göstermektedir. Nesnel yapılandırılmış klinik sınav gibi standartlaştırılmış simülasyon temelli değerlendirmelerin eğitim müfredatına dahil edilmesi, eğitimdeki eksiklikleri belirlemeye ve düşük sıklıkta görülen ancak yüksek etkili olaylara hazırlığı artırmaya yardımcı olabilir.

Anahtar sözcükler: Acil tıp; eğitim; radyolojik ve nükleer; simülasyon; toksikoloji; toksik terörizm.

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