ORIGINAL RESEARCH

Global Characteristics of Chemical, Biological, and Radiological Poison Use in Terrorist Attacks

Burc Aydin, MD

Department of Medical Pharmacology, Sanliurfa Mehmet Akif Inan Research and Training Hospital, Sanliurfa, Turkey

Correspondence:
Burc Aydin, MD
Department of Medical Pharmacology
Sanliurfa Mehmet Akif Inan Research and Training Hospital
Esentepe Mah, Ertugrul Cad, Sanliurfa, Turkey
E-mail: burcaydin@gmail.com

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Abbreviations:
CBR: chemical, biological, and radiological
GTD: Global Terrorism Database
RDWTI: RAND Database of Worldwide Terrorism Incidents

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Abstract

Background: Chemical, biological, and radiological (CBR) terrorism continues to be a global threat. Studies examining global and historical toxicological characteristics of CBR terrorism are lacking.

Methods: Global Terrorism Database (GTD) and RAND Database of Worldwide Terrorism Incidents (RDWTI) were searched for CBR terrorist attacks from 1970 through 2017. Events fulfilling terrorism and poisoning definitions were included. Variables of event date and location, event realization, poisonous agent type, poisoning agent, exposure route, targets, connected events, additional means of harm, disguise methods, poisonings, and casualties were analyzed along with time trends and data gaps.

Results: A total of 446 events of CBR terrorism were included from all world regions. A trend for increased number of events over time was observed ($R^2 = 0.727$; coefficient = 0.511). In these attacks, 4,093 people lost their lives and 31,903 were injured. Chemicals were the most commonly used type of poison (63.5%). The most commonly used poisonous agents were acids (12.3%), chlorine or chlorine compounds (11.2%), riot control agents (10.8%), cyanides (5.8%), and Bacillus anthracis (4.9%). Occurrence of poisoning was confirmed in 208 events (46.6%). Most common exposure routes were skin, mucosa, or eye (57.2%) and inhalation (47.5%). Poison was delivered with additional means of harm in 151 events (33.9%) and in a disguised way in 214 events (48.0%), respectively.

Conclusions: This study showed that CBR terrorism is an on-going and increasingly recorded global threat involving diverse groups of poisons with additional harmful mechanisms and disguise. Industrial chemicals were used in chemical attacks. Vigilance and preparedness are needed for future CBR threats.

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Introduction

Threats of terrorist acts using chemical, biological, and radiological (CBR) weapons continue to exist with emerging and evolving challenges. New terrorist actors and more accessible material, technology, and digitally-shared information contribute to these challenges. These concerns have recently been addressed by North Atlantic Treaty Organization (NATO; Brussels, Belgium), European Parliament, the United States, and the United Nations, and increased preparedness and enhanced security are advised with an emphasis on the management of consequences of actual attacks.[1-5] While individual and manifest incidents of CBR terrorism have been studied extensively within these reports, systematic analyses of historical data and patterns regarding CBR terrorism are lacking.

Review of historical accounts is deemed to be a part of government assessment and preparedness activities for CBR terrorism.[6] Enhancement and dissemination of information and research results to increase preparedness has recently been made an objective of European action plans for CBR risks.[7] Descriptive studies of poisonings in general are also considered to be needed.[8]

This study aims to evaluate enacted or attempted events of CBR terrorism systematically and descriptively with publicly available and historically collated data spanning over 48 years from a medical and toxicological perspective. Details of CBR terrorism events were obtained via dedicated open-access terrorism databases. Outcomes of interest were types of poisonous agents, casualties, and attack and target types along with geographical and temporal patterns to contribute to evidence-based prevention, preparation, and management efforts for countering CBR terrorism and its medical consequences.

Methods

Data Sources

Raw data files (in xls format) were downloaded from two comprehensive, open-access information sources on terrorism: Global Terrorism Database (GTD) and RAND Database of Worldwide Terrorism Incidents (RDWTI).[9,10] The GTD and RDWTI comprise of world-wide data on terrorist events with free and publicly accessible data sets, containing 221,820 entries in total (181,691 in GTD and 40,129 in RDWTI) by download date. The GTD is managed by The National Consortium for the Study of Terrorism and Responses to Terrorism (College Park, Maryland USA) and comprises data mainly derived from news sources from 1970 through 2017 (missing for 1993); RDWTI is organized in-house by RAND Corporation (Santa Monica, California USA) containing data from 1968 through 2009 (partially missing for 2009). Downloaded data files included variables of date, location, terrorist actor, weapon, attack and target types, casualties (fatalities or injuries) with descriptive notes, news headlines, and comments. The GTD compiles relevant data from a universe of world-wide media articles within a well-defined and controlled process with trained and supervised coding teams. Intentional and violent events perpetrated by non-state actors outside the context of legitimate warfare and with specific ideologic goals or intent for coercion or publicizing are included in GTD. Data management of GTD is guided by a codebook explaining data validation methods, inclusion criteria, data variables, and personnel training.[11] While up-to-date external validation and accuracy assessments are lacking for GTD and RDWTI, extensive validation of accuracy of entries and data management strategy of GTD and its predecessors was carried out earlier.[12,13] Additionally, a machine-learning and algorithm study by Ding, et al, which was based principally on historical GTD data from 1970 through 2014, reached an accuracy of 96.0% for predicting places of actual terror attacks carried out globally in 2015.[14]

Definitions

Throughout this study, a modified GTD definition of a terrorist event as "the threatened or actual use of illegal force and violence (by any actor) to attain a political, economic, religious, or social goal through fear, coercion, or intimidation" was used.[11] Poisoning was defined broadly as "a condition or physical state produced by the ingestion, injection, inhalation of, or exposure to a deleterious agent," as described by Medical Subject Headings,[15] and in this context, deleterious agents with in vivo action mechanisms of CBR nature were considered as poisons employed or suspected to be used directly and intentionally against humans within terrorist acts.

Inclusion Criteria, Search Strategy, and Data Preparation

In line with the definitions above, enacted or only attempted terrorist events of poisoning, including events with no casualties and attacks against food or water supplies, within GTD and RDWTI databases were included in the study data set. Events of multiple types of harmful mechanisms were included as well if an intentional poisoning component was present (eg, a bomb containing nails and screws laced with rat poison or smoke inhalation due to arson).

As the total number of database entries was high and entries were not categorized uniformly, a broad search strategy was conducted to identify poisoning events accurately and completely. Both GTD and RDWTI databases were searched for texts containing "poison," "toxic," "toxin," "venom," "exposure," "biological," "radioactive," "radiological," or "chemical" and events found were extracted. A single study data file of these search results was built and every entry was examined for authenticity, duplicity, and connection. As methodological details and validation efforts cannot be accessed for RDWTI, GTD was used as the principal study database and RDWTI entries were compared to GTD entries. Events not fulfilling the definition of poisoning, assaults employing explosives only, attacks against properties only and storage or production facilities of CBR, as well as duplicate entries were excluded, while additional data and connected events were included. The study data file was finalized with variables of date, location, event realization (enacted or attempted), poisonous agent type (CBR or unknown), poisoning agent, exposure route, targets, connection with other events, additional harmful mechanisms and disguise methods, and poisonings and casualties. When data of a single event were ambiguous or conflicting, the most serious or severe data stated were included.

Data Analysis and Ethics

As this study was designed to retrospectively analyze open-access CBR terrorism data from a medical and toxicological perspective, ethics committee review was not sought. Information about perpetrators, motives, and property damages was not recorded. Where mentioned in the GTD and RDWTI databases, identities of individuals were omitted from the study data file. Original sources or additional reports were not consulted to assess data accuracy or to obtain further data. Events considered doubtful fulfilling terrorism or poisoning definition were included in the analysis as claims or suspicions could provide information for possible future attempts. Where an event represented a mix or a continuum of multiple types of harmful mechanisms and related casualties, total number of casualties were included. Medical Subject Headings Tree Structures and definitions were used for the classification of poisonous agents.[15] Data analysis was performed with IBM SPSS Statistics version 20 (IBM Corporation; Armonk, New York USA) and Microsoft Excel 2011 (Microsoft Corporation; Redmond, Washington USA). The study dataset (raw data file in xls format) has been published for future studies in Harvard Dataverse (Harvard University; Cambridge, Massachusetts USA) open-access data repository.[16]

Results

A total of 446 events of CBR terrorism (423 from GTD and 23 from RDWTI) from 1970 through 2017 were included in the study dataset. Forty-nine events (11.0%) were duplicates in both databases while data of eight events (1.8%) were merged from the two databases. Fifty-eight events (13.0%) were considered doubtful by GTD for fulfilling terrorism criteria. Majority of the events (n = 401; 89.9%) were enacted. Casualties were present in 289 events (64.8%). In 111 (24.9%) and 228 (51.1%) confirmed events, 4,093 people lost their lives while 31,903 were injured, respectively. General characteristics of CBR terrorism events are presented in Table 1. A linear regression model of number of CBR terrorism events per year (without an equation constant) yielded a significant trend for increase over time ($R^2 = 0.727$; coefficient = 0.511; $P < .001$). Different types of poisonous agents were not used in any event together. The most commonly used type of poisonous agent was chemical agents (n = 283; 63.5%), whereas in 112 events (25.1%), type of poison was unknown. Of these 112 events where the type of poisonous agent was unknown, 74 (66.1%) happened from 2012 through 2017. One-hundred-and-twenty events (26.9%) were determined to be connected in 31 different terror clusters (median number of connected events per

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Event Characteristic	Number (%)
Poisonous Agent Type	
Chemical	283 (63.5)
Biological	38 (8.5)
Radiological	13 (2.9)
Unknown	112 (25.1)
World Region	
South Asia	109 (24.4)
Middle East & North Africa	94 (21.1)
Western Europe	58 (13.0)
North America	53 (11.9)
East Asia	32 (7.2)
South America	32 (7.2)
Sub-Saharan Africa	20 (4.5)
Eastern Europe	16 (3.6)
Southeast Asia	14 (3.1)
Australasia & Oceania	12 (2.7)
Central Asia	3 (0.7)
Central America & Caribbean	3 (0.7)
Event Type	
Enacted	401 (89.9)
Attempted	45 (10.1)
Terrorism Event Doubtful per GTD	58 (13.0)
Insurgency/Guerilla Action	32 (7.2)
Other Crime Type	15 (3.4)
Lack of Intentionality	9 (2.0)
Intra/Inter-Group Conflict	2 (0.4)
Multiple Type of Harmful Mechanisms Present[a]	151 (33.9)
Explosive	92 (20.6)
Firearm	34 (7.6)
Knife/Other Sharp Object	14 (3.1)
Incendiary	13 (2.9)
Blunt object	7 (1.6)
Other	8 (1.8)
Suicide Attack	17 (3.8%)
Victims or Targets[b]	
Civilians or Civilian Institution	321 (72.0)
Military or Police Personnel	103 (23.1)
Food Supply	34 (7.6)
Diplomatic Personnel or Mission	16 (3.6)
Water Supply	10 (2.2)
Other Terrorist	1 (0.2)
Casualties Present	
Yes	289 (64.8)
No	147 (33.0)
Unknown	10 (2.2)

Table 1. Characteristics of Terrorist Events Employing Chemical, Biological, or Radiological Agents (n = 446)

Abbreviation: GTD, Global Terrorism Database.

[a] In 13 events (2.9%), more than one additional harmful mechanism was present.

[b] In 39 events (8.7%), more than one target or group of victims were attacked.

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cluster = 3; range = 2-10). In 151 events (33.9%), multiple types of harmful mechanisms were present, most commonly an explosive (n = 92; 20.6%) along with a poison. Also, CBR terrorism occurred in all world regions and in 69 countries. The first five countries where CBR terrorism was most commonly encountered were: Afghanistan (n = 79; 17.7%), Iraq (n = 61; 13.7%), United States (n = 48; 10.8%), Japan (n = 26; 5.8%), and United Kingdom (n = 14; 3.1%). From 2012 through 2017, 60 and 79 attacks were carried out in Middle East/North Africa and South Asia, respectively, reaching 79.4% of all events recorded globally within the same period. Civilians were targeted in 321 events (71.9%), followed by military or police personnel (n = 103; 23.1%). Number of CBR terrorism events per world regions and poisonous agent types over years are presented in Figure 1.

Presence of a poison was doubtful in 33 events (7.4%) while poisoning due to an attack was confirmed in 208 events (46.6%) and unknown in 87 (19.5%). In 159 events (35.7%), poison categories were unknown or non-specific. The most common categories of poisonous agents employed in CBR terrorism were: acids (n = 55; 12.3%), chlorine or chlorine compounds (n = 50; 11.2%), riot control agents (n = 48; 10.8%), cyanides (n = 26; 5.8%), and Bacillus anthracis (n = 22; 4.9%). Chemical warfare agents of VX (n = 1), sarin (n = 2), mustard gas (n = 6), and an unknown nerve gas (n = 1) were used in 10 events (2.2%). The most common actual or suspected routes of exposure to poisons were skin, mucosa, or eye (n = 255; 57.2%) and inhalation (n = 212; 47.5%). In 214 events (48.0%), poison was delivered to the victims in a disguised way, most commonly together with explosives, rockets, or projectiles (n = 70; 15.7%); in food items or water supply (n = 62; 13.9%); or in a package, envelope, or letter posted by mail (n = 61; 13.7%). Identified types of poisons (n = 42) employed for exposure via food or water supply were: chemicals (n = 38; 90.5%), biological agents (n = 3; 7.1%), and radiological material (n = 1; 2.4%). Food or water supply was the direct target in 44 events (9.8%). Detailed characteristics of poisonous agents employed in all CBR terrorism events and in events with confirmed occurrence of poisoning are presented in Table 2.

Of data for 208 events with confirmed victims of poisoning, 109 (52.4%) and 94 (45.2%) events lacked information for identification of the causative poison and poisonous agent type, respectively, whereas 50 (24.0%) lacked information for route of exposure. In confirmed poisoning cases, chemicals were the most common type (n = 99; 47.6%) of poisonous agent while biological agents were used in 15 events (7.2%). No confirmed poisoning involved radiological agents. When enacted events were grouped per confirmed occurrence of poisoning (yes or no; 208 versus 193), events with no confirmed poisoning had higher proportions of disguised delivery of poisons (65.3% versus 29.8%) and multiple types of harmful mechanism (53.4% versus 15.9%; chi-square test, P <.001 for both analysis) along with higher numbers of fatalities (3,435 versus 658) and injuries (18,878 versus 13,025).

Discussion

This study showed that events of CBR terrorism were carried out in all world regions with a trend for increasing number of attacks over 48 years. While attacks recently tended to cluster in Middle East/North Africa (mainly in Iraq) and South Asia (mainly in Afghanistan), historical data showed that CBR terrorism is a significant global threat affecting many countries as almost 90% of the attacks were successfully carried out and almost two-thirds left casualties, killing more than 4,000 people and injuring almost 32,000.

Terrorists tended to use one type of poisonous agents (CBR) in any attack, most commonly a chemical substance. One-quarter of the attacks were connected in different clusters, warranting continuous vigilance after a single event. In one-third and almost one-half of all attacks, an additional type of instrument of harm was employed (most commonly an explosive) and poison delivery was disguised (most commonly together with explosive or projectiles or via mail), respectively. These tactics were considered to be employed to increase the chance of successfully enacting an attack, to increase casualties, and to complicate the management and investigation efforts following an attack. This complication factor could explain the observed dramatic increase of disguise and multiple harmful mechanisms in events where occurrence of poisoning was unknown or not confirmed.

While specific agents of true chemical weapons, Bacillus anthracis, ricin, botulinum toxin, or radioisotopes, were identified to be used in numerous events, majority of the attacks used chemical substances which are relatively readily available on the market or field for industrial uses. These toxic industrial chemicals or dual-use agents, such as chlorine, acids, cyanides, and pesticides, have already been addressed as a significant threat and prevention of acquisition of these materials for terrorism has been emphasized.[1,2,4,17,18] Terrorists' access to weapon stockpiles of states (such as chlorine and mustard gas) in active conflict zones is another international concern.[2,4] Contamination of food and water supply was also found to be sought in approximately ten percent of the events. This possible route was previously feared for radiological weapons, yet the study results suggest similar consideration for chemical and biological agents as food or water contaminants.[2]

Details of signs, symptoms, and management of treatment following a CBR terrorism event were largely lacking in data sources and therefore omitted from the study protocol. Presence of additional harmful mechanisms in a considerable number of events was determined to be a significant confounder, along with a data gap which was identified in the databases during the analysis of study data: occurrence of poisoning, identity of the poison, and route of exposure were unknown or non-specific in a considerable number of events. Events occurring in active conflict zones might have jeopardized investigations and reportings and could have contributed to this data gap. These factors prevented further analyses of main causes of casualties, measures of patient decontamination and management, and clinical short- and long-term outcomes related to specific poisons.

Similar reports studying global CBR terrorism exist. A study commissioned by Lloyd's and Chatham House[18] identified 143 CBR attacks in GTD across the world from 1970 through 2014. While the methodology of this study, however, is not provided in detail, the paper provides possible scenarios of CBR attacks, which could be of use for medical training and preparation. A recent study by Santos, et al[19] has analyzed GTD with a different methodology and approach for 292 acts of chemical terrorism, reaching similar results and conclusions for the use of chemical agents in terrorist events. The author believes that the study of Santos, et al and the current study provide complementary information about characteristics of chemical terrorism, such as regional trends, victim subgroups, exposure routes, poison groups, and mortality. This information could be useful for more comprehensive data gathering projects and preparation activities tailored with

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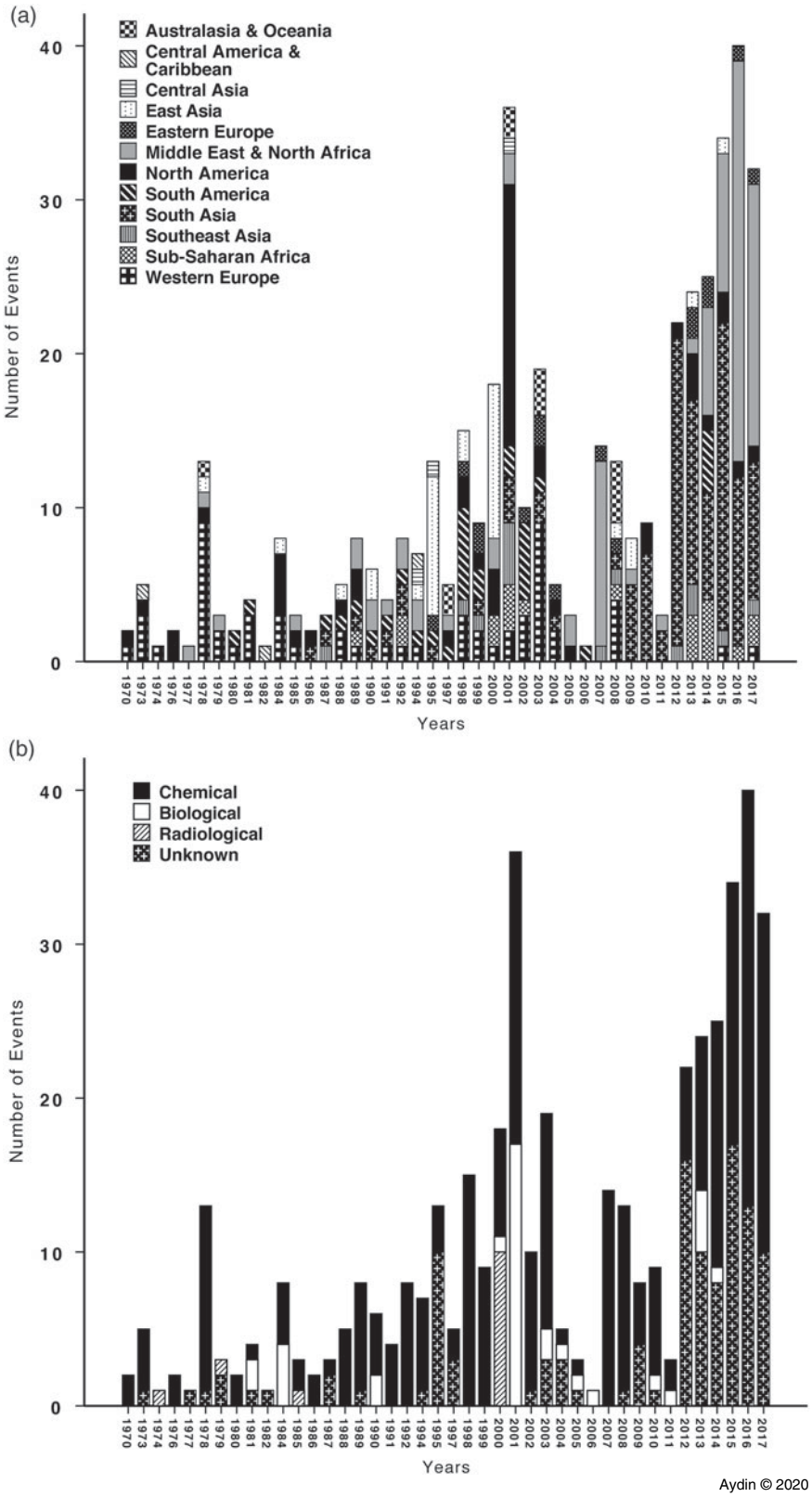

Figure 1. Chemical, Biological, and Radiological Terrorist Attacks between 1970 and 2017 per Year by (A) World Regions and (B) Poisonous Agent Types.

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Characteristic	All Events (n = 446)	Events with Occurrence of Poisoning (n = 208)
Poisoning Occurred		
Yes	208 (46.6)	NA
No	151 (33.9)	NA
Unknown	87 (19.5)	NA
Presence of Poison Doubtful in an Attack	33 (7.4)	9 (4.3)
Poisonous Agent Categories[a]		
Acids	55 (12.3)	34 (16.3)
Chlorine or Chlorine Compounds	50 (11.2)	9 (4.3)
Riot Control Agents	48 (10.8)	19 (9.1)
Cyanides	26 (5.8)	6 (2.9)
Bacillus Anthracis	22 (4.9)	11 (5.3)
Pesticide	15 (3.4)	2 (1.0)
Heavy Metal	12 (2.7)	2 (1.9)
Monazite[b]	10 (2.2)	0 (0.0)
Chemical Warfare Agents	10 (2.2)	3 (1.4)
Arsenic or Arsenical	9 (2.0)	2 (1.0)
Ricin[b]	6 (1.3)	0 (0.0)
Other[c]	36 (8.1)	13 (6.3)
Unknown/Non-Specific	159 (35.7)	109 (52.4)
Actual or Suspected Route of Exposure[d]		
Dermal/Mucosal/Ocular	255 (57.2)	115 (55.3)
Inhalation	212 (47.5)	90 (43.3)
Ingestion	75 (16.8)	31 (14.9)
Parenteral	12 (2.7)	4 (1.9)
Unknown	93 (20.9)	50 (24.0)
Poison Delivered with a Disguised Method[e]	214 (48.0)	62 (29.8)
Together with Explosives, Projectiles, or Rockets	70 (15.7)	5 (2.4)
In Package, Envelope, or Letter Delivered by Mail	61 (13.7)	15 (7.2)
In a Food Item	52 (11.7)	28 (13.5)
In/With a Vehicle	20 (4.5)[f]	6 (2.9)
In Water Supply	10 (2.2)	4 (1.9)
Other	19 (4.3)	7 (3.4)

Table 2. Characteristics of Poisonous Agents Employed in All Chemical, Biological, or Radiological Terrorism Events and in Events with Occurrence of Poisoning

Note: Values are presented as number (%) per column.

[a] In all events and events with poisoning occurrence, 11 (2.5%) and 2 (1.0%) events involved more than one type of poison, respectively.

[b] Monazite was classified as a radiological agent while ricin was classified as a biological agent.

[c] In all events: Ammonia (n=4), anesthetics (n=2), botulinum toxin (n=2), butyrates (n=4), carbon monoxide (n=1), feces (n=1), human immunodeficiency virus (n=1), hydrazine (n=1), hydrocarbons (n=5), nitrogen mustard compounds (n=1), organophosphorus compounds (n=2), phosphorus (n=3), radioisotopes (n=2), salmonella (n=5), sodium hydroxide (n=2). In confirmed poisonings: Ammonia (n=1), anesthetics (n=1), butyrates (n=1), carbon monoxide (n=1), hydrazine (n=1), hydrocarbons (n=1), nitrogen mustard compounds (n=1), organophosphorus compounds (n=1), phosphorus (n=1), salmonella (n=4).

[d] In all events and events with poisoning occurrence, 201 (45.1%) and 82 (39.4%) events involved two types of actual or suspected routes of exposure, respectively.

[e] In all events and events with poisoning occurrence, 19 (4.3%) and 3 (1.4%) events involved more than one method of disguise, respectively.

[f] Of note, drones were used in one attack.

available evidence. Medical and toxicological aspects of preparedness for CBR terrorism constitute toxicovigilance, public and professional training, and supporting health care professionals and infrastructure in actual events. Poison information centers could play a key role in facilitating these efforts.[20,21] Examples of anthrax bioterrorism in United States[22] and mustard gas victims treated in

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Turkey[23] highlight the importance of continuous efforts and collaboration for preparedness within the diverse threat environment of CBR terrorism.

Limitations

This study has several limitations. As mentioned before,[18,24] GTD and probably RDWTI rely on media reports for data gathering and an inherent possibility of bias and data gap exist with this methodology, as mentioned in the results of this current study. Cases with doubtful poisoning information might have contributed as noise as well. Yet, these limitations should be considered within the logistical feasibility of gathering data of terrorist events. This study relied on GTD and RDWTI databases to provide a global toxicological perspective for CBR terrorism. As RDWTI ceded data collection after 2009 and GTD records events only perpetuated by non-state actors, some recent CBR attacks were identified to be not included in this study. Prominent examples are polonium-210 poisoning in United Kingdom[25] and sarin use in Syria.[26]

Additionally, this study excluded attacks against CBR production and storage facilities. Future studies including case presentations and terrorist threats against CBR facilities could provide further information for prevention and preparation activities. Open-access raw data of this current study could be of use for external validation of the study dataset (eg, using available medical literature) and to develop a dedicated global CBR terrorism database for future analyses.

Conclusion

This study showed that CBR terrorism is an on-going and real global threat, which is increasingly recorded in terrorism databases. Diverse groups of poisons were successfully employed in CBR attacks, often disguised and used together with explosives and other harmful means. Use of industrial chemicals for chemical terrorism was observed. Preparedness and risk management plans with available toxicological evidence are of essence to challenge future CBR threats.

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