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Bioterrorism: An analysis of biological agents used in terrorist events

Derrick Tin^{a,*}, Pardis Sabeti^b, Gregory R. Ciottone^a

^a Department of Emergency Medicine, Beth Israel Deaconess Medical Center and Harvard Medical School, USA

^b Harvard University and Harvard T.H. Chan School of Public Health, Broad Institute of MIT and Harvard, Howard Hughes Medical Institute, USA

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ABSTRACT

Background: The Covid19 pandemic has reignited debates and discussions around healthcare systems' biosecurity vulnerabilities and cast a spotlight on the potential weaponization of biological agents. Terrorist and violent extremist groups have already attempted to incite the intentional spread of Covid19 and to use it as an improvised form of a biological weapon. This study aims to provide an epidemiological description of all terrorism-related attacks using biological agents sustained between 1970 and 2019.

Methods: Data collection was performed using a retrospective database search through the Global Terrorism Database (GTD). The GTD was searched using the internal database search functions for all events using biological weapons between January 1, 1970 - December 31, 2019.

Results: 33 terrorist attacks involving biological agents were recorded between 1970 and 2019, registering 9 deaths and 806 injuries. 21 events occurred in the United States, 3 in Kenya, 2 each in both the United Kingdom and Pakistan and a single event in Japan, Columbia, Israel, Russia and Tunisia.

Conclusion: The reported use of biological agents as a terrorist weapon is extremely rare and accounts for 0.02% of all historic terrorist attacks. Despite its apparent rarity, however, bioterrorism has the ability to inflict mass injuries unmatched by conventional weapons. Anthrax has been the most commonly used in previous bioterrorism events with the vast majority of reported attacks occurring in the United States by a single suspected perpetrator. Counter-Terrorism Medicine (CTM) and Disaster Medicine (DM) specialists need to be proactive in delivering ongoing educational sessions on biological events to first responder communities, and anticipate emerging novel biotechnology threats.

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1. Introduction

The Covid19 pandemic has reignited debates and discussions around healthcare systems' biosecurity vulnerabilities and cast a spotlight on the potential weaponization of biological agents. Terrorist and violent extremist groups have already attempted to incite the intentional spread of Covid19 and to use it as an improvised form of a biological weapon [1]. Healthcare impacts of Covid 19 aside, the pandemic has accelerated the spread of extreme ideologies and terrorist organisations have capitalized on anti-government, anti-lockdown sentiments to exacerbate mistrust in public institutions [2,3]. Rapid progress in biotechnologies, gene editing advances, the commercialisation of home Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) kits, and the

widespread data connectivity around the globe pose a significant bioterrorism threat to all [4].

This study aims to provide an epidemiological description of all terrorism-related attacks using biological agents sustained between 1970 and 2019. This data will be useful in the development of education programs in counter-terrorism medicine (CTM), and provide an insight into potential attacks in the future.

2. Methods

Data collection was performed using a retrospective database search through the Global Terrorism Database (GTD) [5]. This database is open-access, with publicly available data collection methodology utilizing artificial intelligence that identifies events from news media around the world, and confirms them through human examination by the National Consortium for the Study of Terrorism and Responses to Terrorism [6]. The GTD defines terrorist attacks as “the threatened or actual use of illegal force and violence by a non-state actor to attain a political, economic, religious, or social goal through fear, coercion, or intimidation.” The GTD does not include acts of state terrorism and links specific event

Abbreviations: CDC, The Centers for Disease Control and Prevention; CRISPR, Clustered Regularly Interspaced Short Palindromic Repeats; CTM, Counter-Terrorism Medicine; DIY, Do-It-Yourself; DM, Disaster Medicine; GTD, Global Terrorism Database.

* Corresponding author.

E-mail address: dtin@bidmc.harvard.edu (D. Tin).

summaries to open-source news articles. Summary of incidents, where provided by the GTD, were included as a supplementary file. Grey literature sources were otherwise used in event summaries.

The GTD was searched using the internal database search functions for all events using biological weapons between January 1, 1970 - December 31, 2019. Years 2020 and 2021 were not yet available at the time of the study.

Results were exported into an Excel® spreadsheet (Microsoft, Redmond Washington, USA) for analysis. Ambiguous events (this field is only systematically available with incidents occurring after 1997) were excluded when there was uncertainty as to whether the incident met any of the criteria for GTD inclusion as a terrorist incident. Attacks met inclusion criteria if they fulfilled the following three terrorism-related criteria, as set by the GTD.

These criteria are determined within the database and not by the authors:

- Criterion I: The act must be aimed at attaining a political, economic, religious, or social goal.
- Criterion II: There must be evidence of an intention to coerce, intimidate, or convey some other message to a larger audience (or audiences) than the immediate victims.
- Criterion III: The action must be outside the context of legitimate warfare activities, i.e. the act must be outside the parameters permitted by international humanitarian law, particularly the admonition against deliberately targeting civilians or non-combatants.

3. Results

33 terrorist attacks involving biological agents were recorded between 1970 and 2019, registering 9 deaths and 806 injuries. 21 events occurred in the United States, 3 in Kenya, 2 each in both the United Kingdom and Pakistan and a single event in Japan, Columbia, Israel, Russia and Tunisia. Table 1 and Fig. 1. It is worth noting that, as per the GTD's codebook, incidents occurring in both the same geographical and temporal point is regarded as a single incident, but if either the time of occurrence of incidents or their locations are discontinuous, the events are regarded as separate incidents. 5 events involving biological weapons were listed as ambiguous or did not meet GTD's 3 terrorism definition criteria and were excluded from this paper.

Of these reported terrorist attacks involving biological agents, 13 targeted government institutions/workers, 6 targeted journalists or media organisations, 4 targeted businesses and 4 targeted private citizens and property. Two attacks were mixed targets (between government, journalist and private citizens) and 1 attack each was recorded against an airport, an educational institution, tourists and 1 attack target was listed as "unknown". Fig. 2.

Twenty of the attacks involved anthrax, 5 involved salmonella, 3 involved ricin, 2 involved faecal matter, 1 involved botulinum toxin, 1 involved the use of HIV infected razor blades and 1 involved either ricin or anthrax. Seven of the recorded deaths were linked to anthrax attacks and 2 remaining deaths were related to salmonella incidents. Of the 806 injuries reported, 776 were related to 2 attacks involving salmonella, 25 were related to anthrax events and 1 was related to an event involving faecal matter as a biological agent. Fig. 3.

Of the 33 terrorist attacks involving biological agents reported from 1970 to 2019, 16 occurred in the year 2001, 12 of them in the United States. There were 4 reported events in 1984 and 2 events reported in each 1981 and 2003. All other years (1990, 2000, 2004, 2005, 2010, 2011, 2014, 2019, 2018) included only a single event. See Table 1 for an overview. More detailed grey literature information was either available in the GTD or found in other open sources, and we provide the summary of these in the Supplemental File provided.

Notably, ten of the US-based attacks reported in 2001 were anthrax-related incidents inconclusively linked to Dr. Bruce Ivins, an American biodefense researcher working at the United States Army Medical

Research Institute of Infectious Diseases (USAMRIID), in Fort Detrick, Maryland. However, Ivins committed suicide in 2008, having not been arrested nor prosecuted. An independent review of the scientific evidence of this possible link by the National Academy of Science indicated that it was "not possible to reach a definitive conclusion about the origins of the anthrax in letters mailed to New York City and Washington, D.C., based solely on the available scientific evidence" [7].

4. Discussion

The Centers for Disease Control and Prevention (CDC) maintains and categorizes a list of bioterrorism agents based on their threat and priority levels [8]. Highest priority Category A agents include: Anthrax, Botulism, Plague, Smallpox, Tularemia and Viral Hemorrhagic Fevers. Category B agents include: Brucellosis, Epsilon Toxin of *Clostridium Perfringens*, food safety threats such as Salmonella, E.coli and Shigella, Glanders, Melioidosis, Psittacosis, Q Fever, Ricin, Staphylococcal Enterotoxin B, Typhus fever, Viral Encephalitis and water safety threats such as *Vibrio Cholerae* and *Cryptosporidium Parvum*. Category C agents, the third highest priority agents include emerging pathogens that could be engineered for mass dissemination in the future because of availability, ease of production and distribution, and potential for high morbidity and mortality rates. Emerging infectious diseases such as Nipah virus and Hantavirus are currently classified as Category C. Coronavirus remains unclassified.

The reported use of biological agents as a terrorist weapon is extremely rare and accounts for 0.02% of all historic terrorist attacks [9,10]. Despite its apparent rarity, however, bioterrorism has the ability to inflict mass injuries unmatched by conventional weapons (mean injury rate of explosives in terrorist attacks = 4./event vs 28.8/event in biological attacks) [9]. Moreover, given the surreptitious nature of these attacks, they are more likely to go unreported than conventional weapons. Research into personal biological threat sensors and advanced bioprotective suits are currently underway, but questions remain in the medical preparedness to respond to bioterrorism events [11]. The recent Covid19 pandemic has exposed significant flaws in biocontainment, disease screening and surveillance, mobilisation of personal protective equipment, medical surge capacities and vaccine countermeasures to biothreats. It has also revealed the complexities around crisis leadership and public education, as evidenced by the inconsistent implementation of and adherence to nonpharmaceutical interventions (NPIs), and global vaccine hesitancy and inequities, all of which could be exploited in the planning of a bioterrorism attack. While the origins of Covid19 remains inconclusive, there has been much debate around the use of modern-day technology to manipulate existing agents or create novel biothreats [12].

Synthetic biology emerged in the 1960s (though it was first coined in the 1910's) but the past decade has seen an explosion of interest, activity and advances in this scientific field [13]. Today, it encompasses specialties such as biotechnology, genetic engineering, molecular biology and biological, electrical and computer engineering [14]. Advances in genetic engineering such as CRISPR technology (often considered to be the most important recent innovation in this field) in particular, has significantly fuelled the growth of synthetic biology [15]. The ability to rapidly edit gene sequences without the need for highly sophisticated and expensive equipment in an institutionalized environment has raised significant concerns around biohacking, a growing biotechnological movement in which individuals can experiment and create entire genomes from scratch (including those of lethal pathogens) with little-to-no safety oversight. Do-it-yourself (DIY) home CRISPR kits already exist on the market today [16].

While the Biological Weapons Convention established in 1975 prohibits the development, production, acquisition, transfer, stockpiling and use of biological and toxin weapons by the 183 states (as of September 2021) that have ratified and acceded the treaty, little can stop rogue actors or terrorist organisations from harnessing existing or creating novel biothreats using the technology available today [17]. Security

Table 1
Reported terrorist events involving biological agents. (Adapted from the GTD).

Date	Country	City	Perpetrator group	Deaths	injuries	Target type	Biological weapon used
28-02-2019	Tunisia	Tunis	Muslim extremists	0	0	Government (General),Journalists & Media,Private Citizens & Property	Ricin or Anthrax
08-09-2018	Russia	Moscow	SERB Group (Russian Liberation Movement)	0	1	Private Citizens & Property,Private Citizens & Property	Faecal matter
01-04-2014	Colombia	Juntas de Birmania	Revolutionary Armed Forces of Colombia (FARC)	0	0	Unknown	Faecal matter
01-10-2011	Pakistan	Islamabad	Unknown	0	0	Government (General)	Anthrax
16-11-2010	United States	Los Angeles	The Justice Department	0	0	Educational Institution	HIV infected razor blades
14-03-2005	United States	Arlington	Unknown	0	0	Government (General),Private Citizens & Property	Anthrax
02-02-2004	United States	Washington	Unknown	0	0	Government (General)	Ricin
12-11-2003	United States	Washington	Unknown	0	0	Government (General)	Ricin
15-10-2003	United States	Greenville	Unknown	0	0	Government (General)	Ricin
14-11-2001	United States	Oxford	Unknown (suspected)	1	0	Private Citizens & Property	Anthrax
23-10-2001	Pakistan	Karachi	Unknown	0	0	Journalists & Media	Anthrax
29-10-2001	United States	New York City	Unknown (suspected)	1	0	Business	Anthrax
26-10-2001	United States	Washington	Unknown (suspected)	0	Unknown	Government (General)	Anthrax
19-10-2001	United States	New York City	Unknown (suspected)	0	2	Journalists & Media	Anthrax
18-10-2001	United States	New York City	Unknown (suspected)	0	1	Journalists & Media	Anthrax
17-10-2001	United States	New York City	Unknown	0	0	Government (General)	Anthrax
15-10-2001	United States	Reno	Unknown	0	0	Business	Anthrax
15-10-2001	United States	New York City	Unknown (suspected)	0	1	Journalists & Media	Anthrax
15-10-2001	United States	Washington	Unknown (suspected)	2	6	Government (General)	Anthrax
12-10-2001	United States	New York City	Unknown (suspected)	0	6	Journalists & Media	Anthrax
11-10-2001	Kenya	Nyeri	Unknown	0	Unknown	Private Citizens & Property	Anthrax
11-10-2001	Kenya	Nairobi	Unknown	0	Unknown	Government (Diplomatic)	Anthrax
11-10-2001	Kenya	Nairobi	Unknown	0	5	Private Citizens & Property	Anthrax
09-10-2001	United States	Washington	Unknown (suspected)	2	1	Government (General)	Anthrax
02-10-2001	United States	Boca Raton	Unknown (suspected)	1	5	Journalists & Media	Anthrax
23-05-2000	Israel	Unknown	Unknown	2	0	Tourists	Samonella Typhi
15-04-1990	Japan	Narita	Aum Shinri Kyo	0	0	Airports and Aircraft	Botulinum Toxin
20-09-1984	United States	The Dalles	Rajneeshees	0	751	Business	Samonella
09-09-1984	United States	The Dalles	Rajneeshees	0	25	Business	Samonella
29-08-1984	United States	Rajneeshpuram	Rajneeshees	0	2	Government (General),Government (General)	Samonella
15-07-1984	United States	The Dalles	Rajneeshees	0	0	Government (General)	Samonella
14-10-1981	United Kingdom	Unknown	Dark Harvest	0	0	Government (General)	Anthrax
10-10-1981	United Kingdom	Trowbridge	Dark Harvest	0	0	Government (General)	Anthrax

Number of terrorist events involving biological agents 1970-2019.

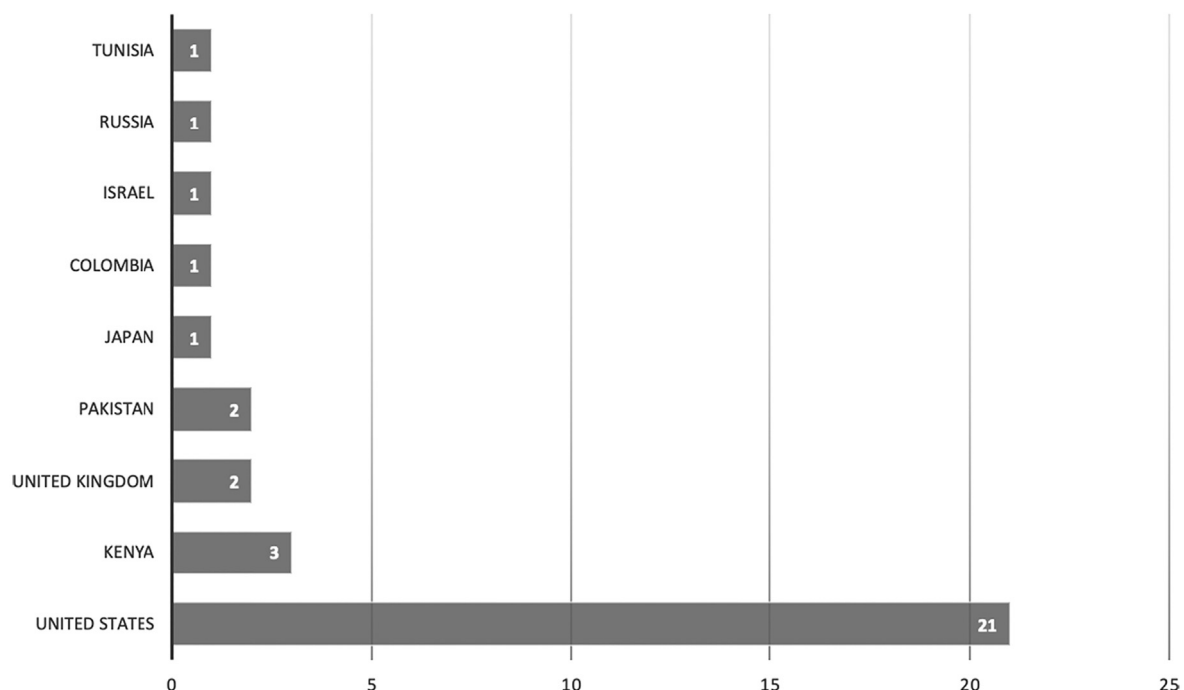


Fig. 1. Breakdown of reported terrorist events involving biological agents, by country.

Bioterrorism: Target types.

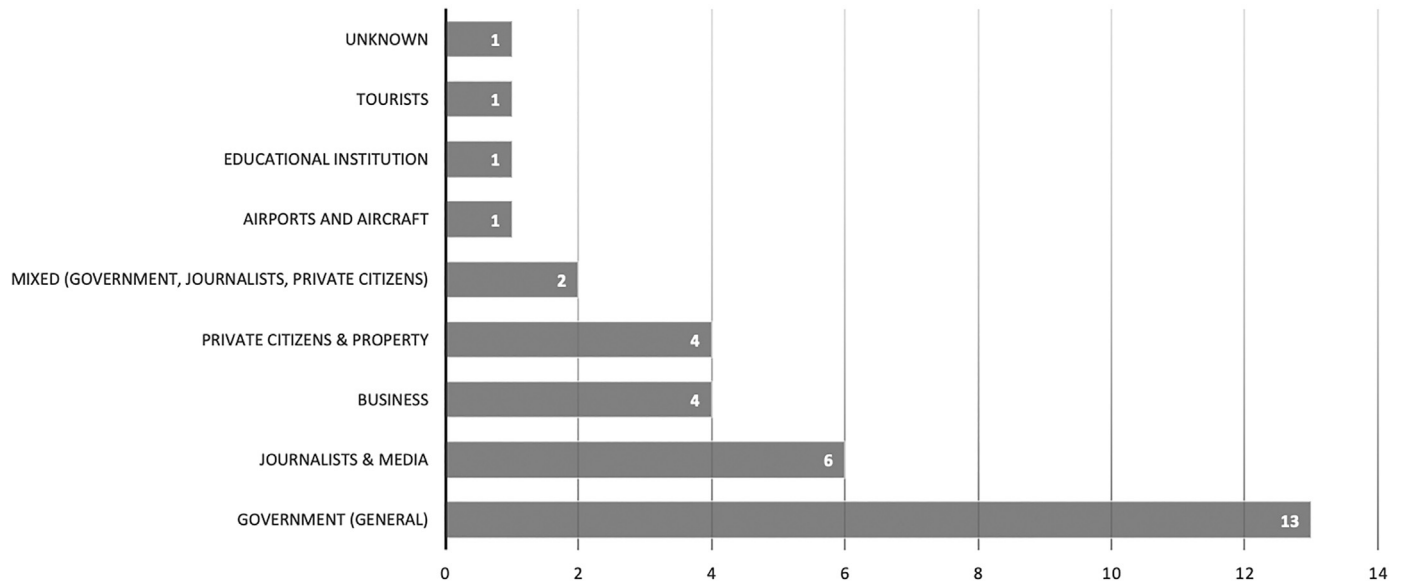


Fig. 2. Breakdown of reported terrorist events involving biological agents, by target type.

concerns range from increasing the lethality or ease of transmission of biological agents to developing novel delivery methods that can overcome preventative vaccine measures [18].

Much has been learned since the beginning of the Covid19 pandemic and expert suggestions in addressing future biothreats include elevating infectious diseases as potential threats to national security, maintaining funding and support to biological research, public health and biological surveillance programs, maintaining medical workforce readiness and improving cross-country collaborations and communication [19].

Bioterrorism highlights the importance of specialist knowledge needed in the field of Counter-Terrorism Medicine (CTM), a subspecialist field of Disaster Medicine (DM). CTM experts need to remain

vigilant in anticipating novel attack methodologies that can threaten healthcare system infrastructures and provide solutions in mitigating the healthcare risks of such attacks. Robust CTM education should be incorporated into traditional DM teachings, as well as emergency medical, nursing and pre-hospital medicine curriculums in an effort to heighten awareness and enhance medical preparedness to future intentional, man-made attacks.

4.1. Limitations

The GTD is a comprehensive record of documented global terrorist events. It is maintained by the National Consortium for the Study

Biological Agents used in terrorist attacks 1970-2019

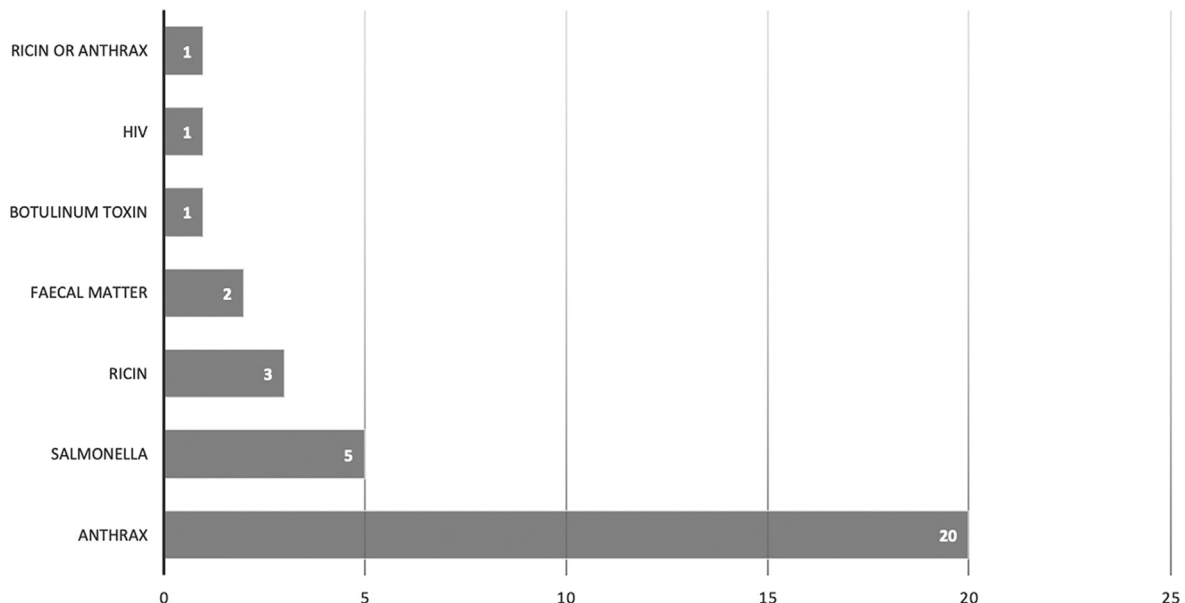


Fig. 3. Breakdown of biological agents used in terrorist attacks.

of Terrorism and Responses to Terrorism, and is the basis for other terrorism-related measures, such as the GTI. Reliance wholly on the GTD is partially mitigated by confirmation with other lay sources, and searches for other online searches, but if there are incidents not reported in the GTD, this could limit the veracity of the findings. Furthermore, the lack of a universally agreed-upon definition of the term terrorism can create inconsistencies between databases in the labelling of such events. Clear and detailed documentation of terrorist events is further hindered by restrictions on reporting, the lack of independent corroboration and the lack of transparency within certain government sources. Infrastructure needed to report, detect and identify biological agents is likely lacking in many parts of the world leading to potential under reporting of events. The greater number reported in the United States may be due to greater scrutiny of potential events. Event descriptions as provided by the GTD rely mostly on grey literature sources and as such accuracy is only limited to those sources.

5. Conclusion

Bioterrorism attacks have been historically rare but have the ability to inflict large-scale, mass casualty events. Anthrax has been most commonly used in previous bioterrorism events with the vast majority of reported attacks occurring in the United States by a single suspected perpetrator. With new advances in microbiology and synthetic biology, it is becoming increasingly possible for individual or small groups of rogue actors to develop and disseminate advanced bioweapons. While the Covid19 pandemic has likely raised the awareness levels of first responders to biothreats, it has also exposed response and preparedness vulnerabilities in the healthcare sector. Counter-Terrorism Medicine and Disaster Medicine specialists need to be proactive in delivering ongoing educational sessions on biological events to first responder communities, and anticipate emerging novel biotechnology threats.

CrediT authorship contribution statement

Derrick Tin: Writing – review & editing. **Pardis Sabeti:** Writing – review & editing. **Gregory R. Ciottone:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ajem.2022.01.056>.

References

- [1] Report. Extortion, bio-warfare and terrorism. [Internet]. UN News: Global Perspective. [cited 2021 Nov 21]. Available from: <https://news.un.org/en/story/2020/11/1077932>
- [2] Hosenball MUS. Homeland security warns fresh COVID-19 restrictions could spark violent attacks | Reuters. [Internet]. Reuters. 2021. [cited 2021 Nov 21]. Available from: <https://www.reuters.com/world/us/homeland-security-warns-fresh-covid-19-restrictions-could-spark-violent-attacks-2021-08-13/>.
- [3] Gates M. Terrorists used COVID-19 pandemic to spread propaganda, exacerbate mistrust, Europol finds. [Internet]. Security Management. 2021. [cited 2021 Nov 21]. Available from: <https://www.asisonline.org/security-management-magazine/latest-news/today-in-security/2021/june/Terrorists-Used-COVID-19-Pandemic-to-Spread-Propaganda-Exacerbate-Mistrust/>.
- [4] Coyne JA. New gene-editing tool could cure disease. Or customize kids. Or aid bioterrorism. Wash Post. 2017. [Internet]. [cited 2021 Nov 21]; Available from: https://www.washingtonpost.com/opinions/new-gene-editing-tool-could-cure-disease-or-customize-kids-or-aid-bioterrorism/2017/06/28/fbe33258-463e-11e7-bcde-624ad94170ab_story.html.
- [5] Global Terrorism Database (GTD) | START.umd.edu. [Internet]. [cited 2021 Jul 18]. Available from: <https://www.start.umd.edu/data-tools/global-terrorism-database-gtd>.
- [6] START.umd.edu | [Internet]. [cited 2021 Nov 28]. Available from: <https://www.start.umd.edu/>.
- [7] Review of the scientific approaches used during the FBI's investigation of the 2001 anthrax letters. National Research Council National Academies Press; 2011. 1–170 p.
- [8] Bioterrorism agents/diseases (by category) | emergency preparedness & response. Centers Dis Control Prev. 2015. [Internet]. [cited 2021 Nov 27]; Available from: <https://emergency.cdc.gov/agent/agentlist-category.asp>.
- [9] Tin D, Margus C, Ciottone GR. Half-a-century of terrorist attacks: weapons selection, casualty outcomes, and implications for counter-terrorism medicine. *Prehosp Disaster Med.* 2021;36(5):526–30.
- [10] Tin D, Granholm F, Hart A, Ciottone GR. Terrorism-related chemical, biological, radiation, and nuclear attacks: a historical global comparison influencing the emergence of counter-terrorism medicine. *Prehosp Disaster Med.* 2021;36(4):399–402.
- [11] Ciottone GR, Tin D, Court M. Counter-terrorism medicine: the time is now. *Cris Response J.* 2021 (September).
- [12] Ma H, Zhu J, Liu J, Zhang X, Liu Y, Yang Q. Hospital biosecurity capacitation: analysis and recommendations for the prevention and control of COVID-19. *J Biosaf Biosecur.* 2020;2(1):5–9. [Internet]. Available from: <https://doi.org/10.1016/j.job.2020.05.001>.
- [13] Cameron DE, Bashor CJ, Collins JJ. A brief history of synthetic biology. [Internet]. *Nat Rev Microbiol.* 2014;12:381–90. [cited 2021 Nov 21]. Available from: www.nature.com/reviews/micro.
- [14] Shapira P, Kwon S, Youtie J. Tracking the emergence of synthetic biology. *Scientometrics.* 2017;112(3):1439–69.
- [15] Heidari R, Shaw DM, Elger BS. CRISPR and the rebirth of synthetic biology. *Sci Eng Ethics.* 2017 Apr 1;23(2):351–63. [Internet]. [cited 2021 Nov 21]. Available from: <https://link.springer.com/article/10.1007/s11948-016-9768-z>.
- [16] Sneed A. Mail-order CRISPR kits allow absolutely anyone to hack DNA [Internet]. *Scientific American.* [cited 2021 Nov 21]. Available from: <https://www.scientificamerican.com/article/mail-order-crispr-kits-allow-absolutely-anyone-to-hack-dna/>
- [17] Vogel KM, Ben Ouagrham-Gormley S. Anticipating emerging biotechnology threats: a case study of CRISPR. *Polit. Life Sci.* 2018;37(2):203–19.
- [18] Kosal ME. Emerging life sciences and possible threats to international security. *Orbis.* 2020 Jan 1;64(4):599. [Internet]. [cited 2021 Nov 21]. Available from: [/pmc/articles/PMC7515815/](https://pmc/articles/PMC7515815/).
- [19] Cullison T, Morrison S. What has Covid-19 taught us about strengthening the DOD's global health security capacities? [Internet]. Center for Strategic and International Studies; 2021. [cited 2021 Nov 21]. Available from: <https://www.csis.org/analysis/what-has-covid-19-taught-us-about-strengthening-dods-global-health-security-capacities>.