



Zoonotic and Parasitic Agents in Bioterrorism

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Abstract

A variety of agents have a potential risk for being used as weapons of biological terrorism. Parasitic and zoonotic agents could contribute to the installation of fear in human population upon intentional addition to their food and water supplies. Detection of diseases in animals and humans maybe essential in predicting a bioterrorism event since most threat agents of bioterrorism are microbes causing zoonotic and parasitic diseases. *Bacillus anthracis*, *Yersinia pestis*, *Varioliar major*, *Francisella tularensis*, some helminthes, Ebola hemorrhagic fever and Coronavirus (COVID-19) have been implicated as zoonotic and parasitic agents of bioterrorism. Government, infectious disease agencies and anti-terrorism bodies should plan ahead on possible vaccines, drugs and consumables that can be used in the cases of such zoonotic and parasitic forms of bioterrorism.

Keywords: Bioterrorism; Zoonosis; Parasites; Coronavirus; Diseases; Biologicals

Abbreviations: COVID-19: Coronavirus; HIV: Human Immunodeficiency Virus; AIDS: Acquired Immunodeficiency Syndrome; SARS: Severe Acute Respiratory Syndrome; CDC: Center for Disease Control and Prevention; HHS: Health and Human Services; FEMA: Federal Emergency Management Agency; DOJ: Department of Justice; EHF: Ebola Hemorrhagic Fever; WHO: World Health Organization.

Introduction

The term "Bioterrorism" also known as biological attack is the intentional release of viruses, bacteria and other germs that can sicken or kill people, livestock or crops. As a result of new world era of terrorism in 21st century, terrorist have employed different types of weapons to kill maim people in soft targets. The risk posed by biological weapons needs evaluation from historical and technological point of view, biological agents are more dangerous and more devastating than other weapons of warfare [1]. The first recorded biological warfare attack was in 1346 during the siege. A well-fortified Genoese-controlled sea port (Feodsija) in Ukraine attacking Tarter force experience devastating epidemic of plague [2].

The plague pandemic (Black death) swept through Europe, the near East and North Africa in the 14th Century which rack the most devastating public health disaster in recorded history [1,3,4]. Given the complex ecology and epidemiology of plague, it is noteworthy to assume that a single biological attack (Zoonosis) was responsible for plague epidemic in Caffa and even beyond the 14th Century plague epidemic in Europe. This work therefore, focuses on the role of zoonotic and parasitic agents in bioterrorism as the threats and antics of bioterrorism is very important and must be taken seriously by all nations.

Zoonosis and Zoonotic Agents

Zoonosis is defined as those diseases and infections which are naturally transmitted between vertebrate animals and man. In an obligate zoonotic disease such as anthrax, transmission occurs only from animal to human whereas in facultative zoonosis, infections are mostly transmitted among humans [5]. Zoonosis is derived from the Greek word for animal "Zoo" and the suffix modification indicating a state or condition "sis" are infectious diseases of humans that originate in animals. Infectious diseases that originates

in humans and move into other animals are commonly described as “reversed zoonosis”. The term zoonosis does not apply unless there is direct transmission to humans from an infected animal. None of these zoonotic diseases are transmitted to humans exclusively by means of food. Food is only occasionally the vehicle of transmission. Since the oral route represents only one of the several possible ways of infection. Zoonosis is not then food borne disease in the general meaning [6].

The majority of emerging viral disease, up to 70 percent represent zoonosis with such prominent examples such as Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome (HIV/AIDS), Influenza, West Nile Disease, Severe Acute Respiratory Syndrome (SARS), Ebola Virus, Rabies etc [7] and recently SARS CoV-2 (COVID-19). Zoonoses have different modes of transmission. In direct zoonosis, the disease is directly transmitted from animals to humans through media such as air (influenza), or through bites and saliva (rabies). In contrast, transmission can also occur via intermediate specie referred to as vector which carries the disease pathogen without getting infected. These zoonotic transmissions can occur in any context in which there is companionistic (pet), economic (farming), predatory (hunting, butchering) or research contact with or consumption of non-human animals, non-human animal products or non-human animal derivatives [8].

Outbreaks of zoonosis have been traced to human interactions with and exposure to other animals. In 2005, the Center for Disease Control and Prevention (CDC) issued an updated list of recommendations for preventing zoonosis transmission in public settings. The recommendations developed in conjunction with the National Association of State Public Health Veterinarians includes; educational responsibility of venue operators; limiting public and non-human animal contact and non-human animal care and management [9]. Zoonotic agents may be said to be any vertebrate animal by or through which man contract or become infected with certain infectious diseases. A zoonotic agent may as well be a bacterium, virus, fungus or other communicable disease agent. Majority of the biological agents that have been considered as weapons are zoonotic. Most zoonotic agents are not highly contagious which will make them relatively easy to be controlled when incorporated into a weapon system and deployed in a tactical situation. Many of these agents are relatively well understood scientifically, and animal species are available in which to model human disease, to test and alter the virulence of the agent, or even to serve as living bioreactors in which to grow agents [10].

Terrorist have an even broader spectrum of zoonotic agents from which to choose from than do military weapons. For example, the terrorist may need a less effective or lower

quality of weapon or a weapon that is effective over smaller distances than will be required for battlefield use. Such reduced requirements might make it possible to produce useful agents and delivery systems using sophisticated equipment. In general, however, zoonotic agents that might prove useful in terrorist attacks must be produced as respirable aerosols, since nearly all of them are not highly contagious [11]. Furthermore, unlike many chemical warfare agents, zoonotic agents are neither volatile nor can they penetrate intact skin. There are number of non-zoonotic human agents (e.g. smallpox virus) or animal agents (e.g. foot and mouth disease virus, hog cholera virus) that are highly contagious and thus might spread through a population without the necessity for weaponization and presentation as respirable aerosols [12]. While some features of zoonotic agents may make them less attractive, for use by terrorist, they typically are harder to produce than say an explosive bomb, and their effect are less immediate. Other characteristics may add to their attraction. One factor is the potential scale of their threats. In the future as biological warfare proliferators introduced advanced technologies into their programs, it is unlikely that zoonotic agents will be broadly displaced; they may actually become a favored target for genetic manipulation [13].

Parasites and Parasitic Agent

Parasites are organisms which live on or in another organism known as the host from the body which it obtains nourishment. There are several parasites in the environment and when they get into a person’s body; his or her health can be affected. Some parasite enters into the body by way of contaminated food or water and some live on the skin and the hair [14]. Most parasites cannot be seen without the help of a magnifying glass. Like a microscope, this is another special instrument which makes things look bigger that they really are. Some adult worms are big enough to be seen without the help of a magnifying glass. It is easy to see where parasites have been such as when they cause rashes on the skin. There are two main classes of parasites that can cause disease in humans. These are protozoa and helminth [15].

Parasitic agent may be a bacterium, virus, or fungus that transmits parasitic infections or diseases. Parasites can live on or in a host and feed off of it. The parasitic agents include helminth, protozoa, ticks, fleas, lice and mites and they cause diseases such as malaria, trichomoniasis and leishmaniasis. Parasitic agents can penetrate the skin and causes harm to its host [16].

Bioterrorism

Bioterrorism is a form of terrorism where there is intentional release of biological agent (bacteria, virus, fungi

or other germs) to cause harm, illness or death of people, livestock and crops. It is an unlawful use of microorganisms to inflict various forms of harm/harmful incidence or injuries in humans, whole population and environment. These microorganisms are used either in their natural state or in denatured form to constitute biological weapons for biological warfare [17]. According to the US Center for disease control and prevention (CDC) bioterrorism is the deliberate release of virus, bacteria, toxins or other harmful agents to cause illness or death in people, animals or plants. These agents are typically found in nature but could be mutated or altered to increase the ability to cause disease, make them resistant to current medicine or to increase their abilities to be spread into the environment. Bioterrorism maybe favored because biological agents are relatively easy and inexpensive to obtain and can be easily disseminated and can also cause widespread fear and panic beyond the actual physical damage. A biological weapon is useful to terrorist mainly as method of creating mass panic and disruption to state or country. However, technologist such as "Bill Joy" has warned of the potential power which genetic engineering might place in the hands of future bioterrorists [18].

Classification of Bioterrorism Agents

Bioterrorism agents can be classified into three main categories in agreement with Ali KE, et al. [19] namely; Category A, B & C.

Category A

Category A biological agents used in bioterrorism can be easily disseminated or transmitted from person which may result in high mortality rate and it has the potential for major public health impact. Agents in this category might cause public panic and social disruption and require special action for public health preparedness. The agents in category A and disease they cause are highlighted below in Table 1.

Agents	Diseases
<i>Bacillus anthracis</i>	Anthrax
<i>Clostridium botulinum</i>	Botulism
<i>Yersinia pestis</i>	Plague
<i>Variola major</i>	Smallpox
<i>Francisella tularensis</i>	Tularemia
<i>Viral haemorrhagic fever</i>	Ebola, lassa fever etc.

Table 1: The agents in Category A and Disease they cause.

Category B

These are the category of agents that are moderately

easy to disseminate. They also result in moderate morbidity rate and low mortality rate and also they require specific enhancement of CDC's diagnostic capacity and enhanced disease surveillance. Agents in category B are highlighted below in Table 2.

Agent	Disease
<i>Brucella spp,</i>	Brucellosis
<i>Salmonella shigella, E. coli</i>	Food safety threats
<i>Burkholderia Pseudomallei</i>	Meloidosis
<i>Chlamydia Psittaci</i>	Psittacosis
<i>Coxiella Burneli</i>	Q fever
<i>Richinus communis</i>	Ricin toxin
<i>Rickettsia Prowazekii</i>	Typhus fever
<i>Vibrio cholera, chyptosporidium parvuum</i>	Water safety threat

Table 2: Agents in category B.

Category C

This category includes emerging pathogens that could be engineered for mass dissemination in the future because of their availability, ease of production and dissemination and also the potential for high morbidity and mortality rates. This category comprises of emerging infectious diseases such as Coronavirus, Nipahvirus and Hantavirus.

Mode of Spread of Zoonotic and Parasitic Agents

Biological agents (zoonotic and parasitic) can be spread through the following ways as also supported by Thavaselvam D and Vijayaraghavan R [20].

- a. **Aerosols:** In military setting, biological warfare agents are mostly to be delivered by aerosols, the optimum particle size is 0.3-5 μ in diameter which is small enough to reach the alveoli when it is inhaled. This can be achieved by aerosols generators mounted in fixed locations or on trucks cars or boats as well as from cruise missiles and planes equipped with tank and spray nozzles. In the bioterrorist setting, aerosols could be disseminated the same way by direct delivery into ventilation or air conditioning systems or via letters or parcels.
- b. **Weather/Climate Factors:** Weather and climatic factors affect the efficiency of such methods including wind velocity and direction, humidity, degree of cloud protection from direct sunlight and rainfall. In optimum circumstances, the distribution of a biological warfare agent from a cruise missile could cover large enough space and produce casualties' equivalent to that due to

fallout from a nuclear device.

- c. **Contaminated Food and Water:** Shigella may be released through the deliberate contamination of food or water supplies during a hypothetical terrorist attack.
- d. **Explosives:** the use of explosive materials by criminals and terrorist groups poses a significant threat in the country. Attacks using explosives and chemical endanger public safety on a large scale and can severely impact the economic and political stability of countries.

Sources of Bioterrorist Activities

- a. **Government /State Sponsored:** The department of Health and Human Services (HHS), Federal Emergency Management Agency (FEMA) and the Department of Justice (DOJ) provides assistance to State and Local Government in enhancing preparedness for bioterrorism and for emergency of all types. Response to a biological agent whether covert or overt would generally begin at the local level with the federal government becoming involved as needed.
- b. **Ideological Extremist:** This refers to an ideology that is considered to be far outside the main stream attitude of the society. This term is usually meant to be pejorative.
- c. **Religious Extremist:** Religious extremism (the state or quality of being extreme) has become the main driver of terrorism in recent years. Before 2000, it was nationalist separatist terrorist organization such as IRA and Chechen rebels who were behind most attacks. The number of incidents from nationalist separationist groups has remained relatively stable in the years since which religious extremism has grown.
- d. **Lone Wolves:** Lone wolf attacks are relatively rare type of terrorist attacks but has been increasing in number. They may be influenced or motivated by the ideology and belief of an external group and may act in support of such a group. In its original sense, a lone wolf is an animal or person that generally lives or spends time alone instead of with a group. The above sources of bioterrorist attacks agrees with Ali KE, et al. [19] and Luciano B, et al. [21].

Types of Bioterrorist Attack

- a. Attack not requiring an epidemiological method to detect.
- b. Attacks requiring the use of epidemiological method to detect and to do so on time or much earlier.
- c. Attacks requiring the use of epidemiological method to

manage effectively.

Exemplary Roles of Zoonotic and Parasitic Agents in Bioterrorism

Bacillus Anthracis

Bacillus anthracis is a zoonotic agent which causes a disease known as "Anthrax". Anthrax makes a good weapon because it can be released quietly and without anyone knowing. The microscopic spores could be put into powders, sprays, food and water. Anthrax has been used as a weapon around the world for nearly a century. In 2001, powdered anthrax spores were deliberately put into letters that were mailed through the US postal system. 22 people, including 12 mail handlers got anthrax and died. *Bacillus anthracis* is a tier one agent because these agents and toxins presents the greatest risk of deliberate misuse with significant potential for mass casualties or devastating effect to the economy, critical infrastructure or public confidence and pose a severe threat to public health and safety. An anthrax attack could take many forms for example, it could be placed in letters and mailed as was done in 2001, or it could be put into food and water. It can also be released into the air from a truck, building or plane. The anthrax aerosol infective dose is between 8000-50000 spores. It only takes a small amount of anthrax to infect a large number of people [19, 22].

Yersinia Pestis

Yersinia pestis is a zoonotic agent that transmit a disease known as plague. It is passed to humans through the bite of flea that has fed on infected rodent. Once a human is infected with plague, the resulting disease can either develop into bubonic plague which is difficult to transmit among humans and fairly easy to treat with antibiotics or if the infection spreads to the lungs, it become pneumonic plague which develops rapidly and does not respond well to antibiotics.

A paper written on the plague and its potential for use in bioterrorism by Riedel S [1] says; "given the presence and availability of plague around the world, the capacity for mass production and aerosol dissemination, the high fatality rate of pneumonic plague and the potential for rapid secondary spread, the potential use of plague as a biological weapon is of great concern".

Variola Major

Another potential agent of bioterrorism that disseminates a disease known as small pox. Unlike anthrax, small pox can spread from person to person. Smallpox is longer a disease of concern in the natural world because concerted vaccination efforts stamped it out and the last naturally spread case

occurred in 1977. However, if someone is to gain access to the smallpox virus it could be an effective weapon spreading quickly and easily between people. It has proved potential as a biological warfare agent even before any possible genetic enhancement in weapon programs. The infective dose of smallpox in aerosol is between 10-100 organisms [19,23].

Francisella Tularensis

Francisella tularensis causes an infection called tularemia. The bacterium can cause infections by entering through breaks in the skin or by being breathed into the lungs. It is particularly infectious and only a small number of organisms need to enter the body to set off a serious bout of tularemia. According to John Hopkins Center for Public Health Preparedness, "aerosol dissemination of *francisella tularensis* in a populated area would be expected to result in the abrupt onset of large numbers of cases of acute, non-specific, febrile illness beginning 3-5 days later with pleuropneumonitis developing in a significant portion of cases". Without antibiotic treatment, the clinical course could progress to respiratory failure, shock and death. These pathogens are an abbreviated selection. Of course, others considered to have potentials as biological weapons includes, brucellosis, monkey pox, viral hemorrhagic fever etc. [24].

Helminths

Helminths pose a number of important characters that makes them theoretical potential bioweapons. The mode of transmission of helminth parasite to humans is through ingestion with food items unlike stochastic biological agents, helminths are taxonomically diverse and domestic or cosmopolitan species are easily collected. Various helminths are known to have a range of distressing and often stigmatizing effect on those infected ranging from lava migrants and neuropathological symptoms and disease caused by many species also has delayed onset, signs and symptoms which are often difficult to distinguish from those other common diseases [25]. Kwak ML [26] and Okonkwo VO, et al. [27] have enumerated some parasites (helminthes) which could be used for bioterrorism to include cestodes- *Taenia solium*, *Spirometra* spp., *Echinococcus multilocularis*, *Echinococcus granulosus*; and nematodes- *Faciola hepatica*, *Schistosoma mansoni*, *Ascaris lumbricoides*, *Ascaris suum* and *Baylisascaris procyonis*.

Ebola Hemorrhagic Fever (EHF)

The recent Ebola hemorrhagic fever outbreaks in Africa, has reinvigorated the discussion on ebola as a potential agent of bioterrorism. Since the first recorded ebola outbreak in Sudan and the Democratic Republic of Congo in 1976, there

have been sporadic outbreak of an endemic nature that have been primarily restricted to Central and West Africa. But the 2014 Ebola outbreak that began in West Africa poses an unprecedented threat and signals the potential for a global pandemic [28]. The infective area of an Ebola outbreak will continue to expand until the infected population is isolated and public health systems can contain the transmission with no further person to person contact. For instance, since the first reported case of Ebola infection from Guinea in March 22, 2014, the epidemic has affected large swaths of Guinea, Liberia and Sierra Leone with widespread transmission within eight months.

Ebola has shown that it can be disseminated in a small area of the target population and transmitted through primary and secondary infection. The mutating factor of Ebola virus increases the risk of spread because it is difficult to predict the incubation time and the time for infection symptoms to appear in victims and though anthrax, small pox and Ebola can all cause fatalities, Ebola causes far more necrosis than the other two bio agents. Ebola therefore has a higher "terror factor". Moreover, the rapid development of the Ebola Virus within the infected individual and person to person transmission which help to create mass public panic, serves the purpose as bioterrorism agent [29].

Coronavirus (COVID-19)

Coronavirus has been traced to 1918, 1968, 1975, 1997, 2005, and at the moment 2020 after 100 years to have animal and human linkage in transmission. It is zoonotic as animals to human have been confirmed [30,31]. WHO [32] posits that the source of the virus was not very clear, though thought to have originated from animals; the human-to-human transmission has been documented on multiple occasions. There are several possibilities that exist which includes direct contact with an infected animal, which could be either the reservoir species or an intermediate host species; contact with or consumption of unprocessed animal products; contact with the environment where an infected animal has recently been; or consumption of a food or beverage which has been contaminated by animal excreta thereby implicating coronavirus as zoonotic infections.

WHO [33] confirmed coronavirus (COVID-19) is a zoonotic virus as a result of phylogenetics analyses which revealed the genome sequences to be that of bats appearing to be the reservoir of COVID-19 virus, though the intermediate host(s) has not yet been identified. Game animals, Dogs, Camel, Cat, etc. have been suggested as intermediate host [34] though not confirmed especially with the current COVID-19 pandemic. Many questions [35-37] are still flying on the bioweapon potentials of COVID-19.

Conclusion

With zoonotic and parasitic agent as the most likely infectious agent to be used by bioterrorist, humans and veterinary medicine can benefit from cross collaboration. There is therefore, urgent need to galvanize communication flow among medical and veterinary practitioners [38], researchers and policy makers in the case of an anticipation of bioterrorism zoonotic and parasitic escape or attack early enough to help and curtail of spread in any given human population or the world at large. Majority of the emerging infectious diseases including those caused by bioterrorist agents are zoonotic and parasitic.

Adequate understanding of such zoonotic parasitic agents are germane to have a knowledge base of better handling in cases of occurrence especially the full knowledge of handling such cases in clinical and hospital environment [39] is also key to management and prevention. Appropriate dispersion of even a small volume of biological warfare agent may cause high mobility and mortality which may be exacerbated by public and social disruption just as it is expected currently with coronavirus (COVID-19) pandemic.

Recommendation

For communicable diseases in particular, given the potential for initial exponential growth in the number of cases from a single diseased individual, it is crucial that a variety of methodologies, both prophylactic and reactive be developed for limiting spread. These include vaccination, treatment, quarantine, movement restrictions, isolations and in the case of none human populations, culling. Studies must be done to develop decision rules and procedures for quarantine. These studies must be conducted with the goal of ultimately involving active participation of communities well before any event occurs. This will help reduce panic and irrational behaviour in the case of an actual or suspected bioterrorism event. Quarantine communities must know where they will get medical care, antibiotics and vaccines, clean water and food.

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