Journal of Bioterrorism & Biodefense

Kwak, J Bioterror Biodef 2016, 7:3
DOI: 10.4172/2157-2526.1000148

Review Article Open Access

Helminths as Weapons of Bioterrorism: an Unrecognised Threat

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Received date: June 23, 2016; **Accepted date:** July 16, 2016; **Published date:** July 22, 2016

Abstract

Parasitic worms, more commonly known as helminths, have a significant effect on global human health. However, this group of pathogens has been overlooked by bioterrorism researchers and analysts as possible agents which may be weaponised and deployed by terrorist groups or rogue states. For the first time, the dangers posed by these agents are highlighted along with the potential of the group for weaponisation. The first biodefense strategies against helminthic bioweapons are also proposed.

Keywords: Parasites; Biodefense; Bioweapons; Foodborne; Nematode; Trematode; Cestode; Terrorism; Public health; Rogue state

Bioweapons

The 21st century has been called 'The Age of Terrorism' due to the number of terrorist attacks which have occurred internationally in the past 15 years [1]. Traditionally, security concerns have been focused on nuclear and bomb threats. However, in recent years concerns over biological weapons have increased [2]. This is due in part to many cases of the development of bioweapons by terrorists in the past decades, most notably Aum Shinrikyo in Japan and the anthrax letter terrorist in the USA [3,4]. It is also due to the increased availability of information and technology required to weaponising biological agents [5].

Bioweapons are formidable for a number of reasons. Most importantly they are as effective, if not more effective than nuclear or chemical weapons due to the transmissibility of many agents and their ability to inflict high levels of morbidity and mortality [6]. Bioweapons are also extremely cheap to produce compared with nuclear weapons which require enriched radioactive elements or chemical weapons which often require controlled or difficult to produce compounds [7]. The equipment needed to produce bioweapons is also largely unregulated due to its common use in the education, agricultural and research industries [8]. Low technological and knowledge barriers to the production of bioweapons mean that individuals untrained in biological science may still be able to successfully weaponise and disperse biological agents [1]. Most importantly, the delayed effect of biological weapons allows for undetected release and ease of escape by those perpetrating a biological attack [2]. These qualities coupled with the proposed under preparedness of most developed nations to such attacks make biological weapons a fearsome threat to state security and public health [9].

Helminths as Bioweapons

Contemporary focus on bioweapons has been largely directed towards bacterial and viral agents as well as biological toxins [10]. Prions and fungal pathogens have also been discussed to a limited extent [1,11]. However, despite their wide public health impacts and at least one recorded case of helminths having been used as a bioweapon, the group has received little attention [12].

Helminth poses a number of key biological characters making them theoretically dangerous and effect bioweapons and of potential interest to both state and non-state actors. The risk of accidental exposure to these agents by those weaponising them is far less likely than that of more common biological agent due to the fact that most helminthic infections originate from ingesting contaminated food [13]. This makes helminths attractive to non-state actors which would likely be less technologically equipped for weaponising biological agents. The group is taxonomically diverse and many potentially dangerous helminths are ubiquitous, commonly being found in domestic or cosmopolitan species and easily collected [14]. This suggests that sourcing such agents is cheap, simple and can be done without the notice of local, national, or international security organisations [15]. The low risk of transmission of helminths makes this group very attractive to state and non-state actors seeking to target individuals or specific groups. Various helminths are also known to have a range of distressing and often stigmatising effects on those infected, including larval migrans and neuropathological symptoms [16]. Disease caused by many species also has a delayed onset and signs and symptoms are often difficult to distinguish from those of other more common diseases [16].

Bioweaponisation and Deployment

Compared with the technology and knowledge required to weaponise other pathogenic organisms, namely bacteria and viruses, the weaponisation of helminths is conceivable simple, low risk and inexpensive. The production of helminth bioweapons can be separated into three main phases: acquisition, purification, and weaponisation.

The acquisition phase involves both collecting and culturing or simply collecting infectious material from the environment with the intention of obtaining a large enough amount for weaponisation. Due to extensive research into the lifecycles of many cosmopolitan helminth species, the lifecycles of most have been elucidated, making collection of material from the environment relatively simple. Due to research into the fundamental and applied biology of many helminth pests, techniques have also been developed for in vitro culturing of many common species [17]. Extensive taxonomic guides and keys to the identification of common helminths also exist, making identification simple.

Research into the diagnostics of helminths has led to the development of many techniques for the concentration of both larvae and ova of most groups. Various floatation methods have been developed for the concentration of ova and several techniques have also been developed for concentrating the infectious larval stages [15]. This means that there would be no technological barrier to those wishing to purify and concentrate the infectious stages of most common helminths.

The weaponisation phase of production involves converting concentrated infection material into a form that can easily be used to dose foods or liquids with high enough numbers of infectious stages to cause disease in targets. Due to the ability of many species of helminths to survive long periods in the environment many have adaptations making their weaponised state far less susceptible to degradation in the environment than many more conventional agents [18].

Potential Candidates

Thousands of helminth species are known, however, the number which may be suitable candidate species for bio-weaponisation is low. Potential candidate species would likely share a number of common similarities, namely: ubiquity, ease of weaponisation and high pathogenicity.

Ubiquity in this context refers to a number of characters. Primarily, the candidate species would likely be a parasite of a common, probably cosmopolitan host, such as a domestic animal, or humans in developing countries. The parasite would also likely be common in its host species. Ease of weaponisation refers to the simplicity with which the species can be collected, cultured/purified and then prepared for dispersed. This is largely based upon the complexity of the technical and knowledge barriers to weaponisation. These barriers would primarily relate to the collection, identification and purification of the helminth as well as the level of parasitological knowledge those undertaking the weaponisation possess. It should be noted that a certain level of knowledge regarding helminth biology would be required to weaponise these agent. High pathogenicity refers to the level of disease which infection with the parasite causes in the target. Highly pathogenic species would likely cause serious morbidity and/or mortality in those infected. While humans are the most likely targets, in some circumstances, livestock may also be targeted. Listed in Table 1 are some species with the traits discussed above which may be used as bioweapons in the future along with basic biological data from the literature [15-19]. While Table 1 lists a number of the most likely candidate species, this list is by no means complete as there are many other species which may be suitable candidates.

Species	Group	Distribution	Final Host(s)	Disease
Taenia solium	Cestode	Worldwide	Pigs	Cysticercosis
Spirometra spp.	Cestode	North America & Australasia	Canids, Felids, Racoons	Sparganosis
Echinococcus multilocularis	Cestode	Northern Hemisphere	Foxes & Dogs	Alveolar echinococcosis
Echinococcus granulosus	Cestode	Worldwide (in sheep areas)	Canids	Unilocular hydatidosis
Schistosoma mansoni	Trematode	Worldwide	Humans	Schistosomiasis
Fasciola hepatica	Trematode	Worldwide	Cattle, Goats, Sheep, Kangaroos	Fascioliasis
Ascaris suum	Nematode	Worldwide	Pigs	Ascariasis
Ascaris lumbricoides	Nematode	Worldwide	Humans	Ascariasis
Baylisascaris procyonis	Nematode	North America, Europe, Japan	Racoons	Cysticercosis

Table 1: Common *helminth* species which may be deployed by bioterrorists.

Biodefense

Biodefense is often considered to be a complicated and expensive undertaking, but nevertheless necessary [20]. While *helminthic* bioweapons are unlikely to be transmitted between people after the initial biological attack, there is still need for biodefense programs to focus on these pathogens. Biodefense against helminthic bioweapons requires a multidisciplinary approach primarily engaging the agricultural and public health sectors.

Initially governments should seek to identify those species most likely to be used as agents by bioterrorists in their particular regions. Based on this information, the public health sector must develop diagnostic and treatment protocols for victims of such biological attacks. Diagnostic screening should include multiple methods such as genetic, immunological, histopathological and morphological tests which, although time consuming would provide a more accurate diagnosis than single method diagnostic protocols. This is due to the diverse nature of helminth infections by different groups and life stages [21]. While it has been suggested that helminths of medical importance be listed as reportable diseases, helminths are largely unreported or underreported in most developed nations [22]. Infections caused by common helminth species with the capacity for weaponisation should be designated as reportable diseases. This designation would allow for epidemiological patterns to be more easily spotted which may be particularly difficult in some helminth infections due to the often slow onset and the often general nature of signs and symptoms [16].

The agricultural sector should be engaged to control common helminth species in livestock with the capacity for weaponisation. Wide scale eradication of helminths in livestock has been suggested as feasible in the past, using drugs and/or vaccines [23,24]. This type of wide scale eradication project could be employed not only to wipe out agents likely to be employed as bioweapons but also to increase the health and production output of livestock.

An argument could be made that greater surveillance and testing of food for the presence of food-borne helminths should be undertaken. However, in most developed nations food-borne disease surveillance systems are will funded and sophisticated [25,26]. As biological attacks employing helminthic bioweapons are most likely to occur at post-surveillance stages of the food production process such as in supermarkets or food festivals, greater surveillance is unlikely to make a difference to the risk of this type of biological attack occurring.

Conclusions

Helminths are a largely unrecognised but ubiquitous group of parasites which pose a significant risk to human health if weaponised by bioterrorists or rogue states. Not only can they be easily collected and weaponised but infection by many common species can cause significant disease in humans. The low knowledge and technological barriers to their weaponisation also make them attractive to groups with low technological capabilities. Biodefense protocols should be developed to prepare for potential future attacks employing helminths and overall, greater attention should be payed to this group of biological agents by health sectors, security agencies and governments.

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