



CHRISTMAS 2015: INFECTION CONTROL

Zombie infections: epidemiology, treatment, and prevention

Tara C Smith summarises the epidemiology and pathology of zombie infections and calls for research and funding to prevent a zombie apocalypse

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Zombies—also known as walkers, Zed, Zs, biters, geeks, stiffs, roamers, Zeke, ghouls, rotters, Zoms, and runners—have become a dominant part of the medical landscape. Zombie expert Matt Mogk defines a zombie with three criteria: it is a reanimated human corpse; it is relentlessly aggressive; and it is biologically infected and infectious.¹ But Mogk notes that this definition has been altered by the recognition of “rage” zombies, which are infected but still alive. They are more closely related to vampires infected with the contagious bacterium *Bacillus vampiris*.² Here, I review zombie biology and epidemiology.

History

Descriptions of zombies date back to the 1500s.³ Haitian zombies are probably the best described, often thought to be controlled by practitioners of voodoo.⁴ They may have been created via a neurotoxin, typically described as tetrodotoxin, which puts the victim in a sleep-like state.⁵ These voodoo or chemical zombies seem to be unrelated to the current wave of epidemics, which began with the first documented outbreak in 1968 (fig 1).⁶ The modern outbreaks are thought to be infectious in aetiology and transmissible by bite.

The Solanum virus is the most extensively studied infectious cause of reanimated zombies.⁷⁻⁹ It has caused outbreaks around the world but does not have an identified reservoir in nature.⁸ It has a 100% mortality rate, and zombification is certain in anyone exposed to an infected person. Solanum infection is universally fatal in all animals tested or observed, indicating that zoonotic transfer to humans is an unlikely origin.⁸ One anecdotal report linked infection to the looting of underwater settlements in the Three Gorges Dam in China.⁹ A child emerged, bitten, but his fishing partner did not surface at all. The dam was created by relocating over 1.24 million residents and flooding their former villages.¹⁰ Zombie expert Max Brooks thinks that Solanum virus infection has occurred for thousands of years and is now emerging because of urbanisation and the

interconnected nature of commerce and travel.⁸ Whether this virus is the cause of the current outbreak in the United States has not been tested.^{11 12}

Although reanimated zombies have been documented for potentially millennia,⁸ rage zombies seem to be a more recent phenomenon. These date back to at least 1973, when the weaponised Trixie virus was accidentally released in Pennsylvania.¹³ This virus was also responsible for a 2010 outbreak in Iowa.¹⁴ In both cases a military plane carrying the virus—a modified form of rhabdovirus—crashed into a small town’s water supply. Townsfolk were infected via ingestion of the virus and possible airborne spread. Infection caused the inhabitants to develop a murderous rage. The outbreak was quashed by a controversial military intervention and forced quarantine, but at a high cost of lives (fig 2). Infected people may remain.

A 2002 epidemic of rage zombies decimated London, UK, leading to quarantine of the island of Britain.¹⁵ This outbreak was traced back to the release of a genetically modified virus derived from Ebola that was tested in captive chimpanzees.¹⁶ An animal rights activist was bitten while trying to liberate the chimpanzees from a laboratory in Cambridge. Because the incubation period of the virus is short (seconds), and the victims are quick and strong, the infection rapidly spread across the country, necessitating a complete border closure (fig 3). Twenty eight weeks into the outbreak, after many of the zombies had died from starvation, a rare asymptomatic carrier of the virus was discovered, beginning a second wave of infections.¹⁷

Symptoms and incubation period

Symptoms of infection tend to be fairly uniform, regardless of the nature of the pathogen, but the incubation period is highly variable, with time to development of symptoms ranging from seconds¹⁵⁻¹⁷ to hours or days.^{11-14 18} Infected people may clinically

die and reanimate,^{6 9 11 12 19-21} or they may remain alive but with the same aggressive tendencies and taste for human flesh as reanimated zombies.¹³⁻¹⁷ Other symptoms may include a shambling gait, tendency to moan, loss of dexterity and prior personality traits, and the eventual rotting of flesh. In rare cases zombies may be highly intelligent, self aware, and lacking in the typical tendencies to bite and eat flesh.^{13 14}

Aetiology and transmission

What unites many outbreaks is transmission via bite. Other ways of becoming infected include insect vectors,^{22 23} animal bites,^{15 19 24} and a ubiquitous condition whereupon everyone reanimates as a zombie upon death.^{11 12 22 24} Insect vectors seem to be rare, but include bedbugs in an island outbreak off the coast of South America²³ and mosquitoes as a vector of the modified Kellis-Amberlee virus.²²

Others types of pathogen have been reported. The causative agent of the zombie outbreak discovered retrospectively on the Titanic was a weaponised form of the bubonic plague bacterium, *Yersinia pestis*.²⁵ *Cordyceps* fungus has been documented as the cause of a diverse set of zombie phenotypes,²⁶ spread via bite or by spores released from dead hosts. A mutated strain of bovine spongiform encephalopathy—a prion infection—led to a US outbreak of zombiism.¹⁸ In other cases, a combination of pathogens has been identified as necessary and sufficient to cause zombification.^{20 21}

Treatment and prevention

Because of the rapid onset of zombie outbreaks and their society destroying characteristics, prevention and treatment are largely unexplored. Severing the bitten area from the body has proved successful in some cases^{11 12} but is not universally preventative, and it is sometimes impossible owing to bite location or the speed of viral incubation.^{15 17} Vaccines have been difficult to study because of the associated cost and the inadequacy of many laboratories to provide proper containment of zombie pathogens or infected zombies, as well as the diversity of zombifying agents. Vaccine hesitancy may make it difficult to achieve society-wide uptake of a zombie vaccine.²⁷ Even if an effective treatment were developed, it may need to be taken perpetually to prevent the affected person from reverting to zombiism.²⁸ More research in this area is sorely needed.

Ethical considerations

Zombie outbreaks are expensive, difficult to control, and have deleterious effects on the stability of life. Quarantines often fail or are unable to accurately contain people who may be infected but not yet symptomatic, resulting in a de novo outbreak within the quarantine facility.^{13 14 17} Resources often become depleted, and zombies can over-run cities or entire countries in days to weeks.^{9 15} Complete containment of the zombie infection is rarely achieved. A notable exception may be the 2004 London outbreak, where the government stemmed the infection with a military response, and remaining zombies were used for labour and entertainment.²⁹

Several models of zombie infections have shown that in the event of a large scale outbreak (for example, zombie entry into a city of 500 000 or more) humans face extermination.³⁰ Chances of survival start out slightly higher in sparsely populated areas, but they eventually become overwhelmed.^{8 31} The Centers for Disease Control and Prevention and others have published details of the preparations that should be made in the case of a

pending zombie outbreak.^{7 32 33} Unfortunately most countries remain grossly unprepared for a potential disaster of this nature.

Discussion

The documented rise of multiple zombie pathogens should be a wake-up call to the international community that we need additional funding and cooperation among scientists and government officials to tackle the looming threat of apocalyptic disease. We need a frank discussion of the ethical and potential criminal problems associated with dealing with zombies. Will people be prosecuted for killing a zombie or a person who has been bitten but has not yet “turned”? Is mass quarantine of those who have been exposed to a zombie but not bitten legal? How would it be achieved?

The use of zombie pathogens as bioweapons is another critical area of investigation and policy planning. Deliberately engineered pathogens have been implicated in several zombie outbreaks,^{13 14 20 24} although their release is almost always accidental or has unforeseen consequences.^{15 16} Defensive work on zombie pathogens is necessary and must be carried out in well equipped and highly contained laboratories.

Some experts have argued that the rise in zombie infections is due to increased surveillance.⁸ Brooks thinks otherwise, citing documentation of zombie outbreaks from antiquity to modern day as evidence of a true rise in incidents. He notes: “At this rate, attacks will only increase, culminating in one of two possibilities. The first is that world governments will have to acknowledge, both privately and publicly, the existence of the living dead, creating special organizations to deal with the threat. In this scenario, zombies will become an accepted part of daily life—marginalized, easily contained, perhaps even vaccinated against. A second, more ominous scenario would result in an all-out war between the living and the dead.”⁸

For the sake of humanity we must ensure that such a war does not occur and that we work together as a unified global community to respond quickly to any and all new zombie threats.

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- Mogk M. Everything you ever wanted to know about zombies. Gallery Books, 2011.
- Matheson R. I am legend. Macmillan, 1954.
- Ackermann H-W, Gauthier J. The ways and nature of the zombi. *J Am Folklore* 1991;104:466-94.
- Littlewood R, Douyon C. Clinical findings in three cases of zombification. *Lancet* 1997;350:1094-6.
- Davis EW. The ethnobiology of the Haitian zombi. *J Ethnopharmacol* 1983;9:85-104.
- Romero G. Night of the living dead. 1968.
- Stanley D. The nurses' role in the prevention of Solanum infection: dealing with a zombie epidemic. *J Clin Nurs* 2012;21:1606-13.
- Brooks M. The zombie survival guide. Three Rivers Press, 2003.
- Brooks M. World war Z. Three Rivers Press, 2006.
- Yardley J. Chinese dam projects criticized for their human costs. *New York Times* 2007 Nov 19. www.nytimes.com/2007/11/19/world/asia/19dam.html.
- Darabont F. The walking dead. 2010.
- Kirkman R. The walking dead. Image Comics, 2003.
- Romero G. The crazies. 1973.
- Eisner B. The crazies. 2010.
- Boyle D. 28 days later. 2002.
- Niles S. 28 days later: the aftermath. Dey Street Books, 2007.
- Fresnadillo JC. 28 weeks later. 2007.
- Fleischer R. Zombieland. 2009.
- Maberry J. Rot and ruin. Simon and Schuster, 2011.
- Schlozman S. The zombie autopsies. Grand Central Publishing, 2011.
- Maberry J. Flesh and bone. Simon and Schuster, 2012.
- Grant M. Blackout. Orbit, 2012.

- 23 Cummings P. The neuropathology of zombies. Sinister Press, 2001.
- 24 Grant M. Feed. Orbit, 2010.
- 25 Pauls C, Solomon M, Deck Z. Chronicle Books, 2012.
- 26 Druckmann N, Straley B. The last of us. Sony Entertainment, 2013.
- 27 MacDonald NE, SAGE Working Group on Vaccine Hesitancy. Vaccine hesitancy: definition, scope, and determinants. *Vaccine* 2015;33:4161-4.
- 28 Cruse C, Tucker R. The returned. 2015.
- 29 Wright E. Shaun of the dead. 2004.
- 30 Munz P, Hudea I, Imad J, Smith RJ. When zombies attack! Mathematical modelling of an outbreak of zombie infection. In: Tchuente JM, Chiyaka C, eds. Infectious disease modelling research progress. Nova Science Publishers, 2009: 133-50.
- 31 Alemi AA, Bierbaum M, Myers CR, Sethna JP. The statistical mechanics of zombies. Abstract S48.00008. American Physical Society March Meeting. San Antonio, Texas, 2-6 March 2015.
- 32 Centers for Disease Control and Prevention. Zombie preparedness. www.cdc.gov/phpr/zombies.htm.
- 33 Nasiruddin M, Halabi M, Dao A, Chen K, Brown B. Zombies—a pop culture resource for public health awareness. *Emerg Infect Dis* 2013;19:809-13.

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Figures



First documented US outbreak in 1968⁶



Military response to 2010 outbreak of rage zombies in Iowa¹⁴



2002 outbreak of rage zombies in the UK¹⁵