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Defending Public Health: The Implications of Targeting Infection Rate and Infection Sources in Emerging Infectious Diseases

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Abstract

Emerging infectious diseases pose a significant threat to global health, as they can rapidly spread and cause severe illness or even death. Understanding the factors that contribute to their transmission is crucial for effective prevention and control strategies. In particular, the infection rate and identification of infection sources play pivotal roles in managing and containing these outbreaks. This article explores the significance of infection rate and infection sources in the transmission of emerging infectious diseases.

There are many prevention and control measures for emerging infectious diseases. This paper divides the effects of these measures into two categories. One is to reduce the infection rate. The other is to use diagnosis rate to reflect the decreases of the infection source. The impacts of measures intensity, diagnosis rate, and the start time of taking measures on emerging infectious diseases with infectious capacity during the incubation period are considered comprehensively by using a differential equation model. Results show that for each diagnosis rate, the number of infections and deaths has a phase change structure with respect to the measures intensity. If the measures intensity is less than the value of the phase change point, the epidemic will break out whenever measures are taken.

Introduction

In premodern times, colonization, slavery and war led to the global spread of infectious diseases, with devastating consequences. Human diseases such as tuberculosis, polio, smallpox and diphtheria circulated widely, and before the advent of vaccines, these diseases caused substantial morbidity and mortality. At the same time, animal diseases such as rinderpest spread along trade routes and with travelling armies, with devastating impacts on livestock and dependent human populations [1]. However, in the past two decades, medical advances, access to health care and improved sanitation have reduced the overall mortality and morbidity linked to infectious diseases, particularly for lower respiratory tract infections and diarrhoeal disease. The swift development of the severe acute respiratory syndrome coronavirus 2 vaccine speaks to the efficacy of modern science in rapidly countering threats from emerging pathogens. Nevertheless, infectious disease burden remains substantial in countries with low and lower-middle incomes, while mortality and morbidity associated with neglected tropical diseases, HIV infection, tuberculosis and malaria remain high. Moreover, deaths from emerging and re-emerging infections, in comparison with seasonal and endemic infections, have persisted throughout the twenty-first century. These points to a possible new era of infectious disease [2], defined by outbreaks of emerging, re-emerging and endemic pathogens that spread quickly, aided by global connectivity and shifted ranges owing to climate change.

Infection rate: The measure of disease transmission

The infection rate, also known as the basic reproduction number (R0), is a critical metric in assessing the transmissibility of an emerging infectious disease. It quantifies the average number of secondary cases resulting from a single infected individual in a susceptible population.

Several factors influence the infection rate, including the mode of transmission, the pathogen's characteristics, and population behavior. Diseases transmitted through respiratory droplets, such as influenza and COVID-19, tend to have higher R0 values compared to those transmitted primarily through direct contact or vector-borne routes. Understanding the mechanisms of transmission and the potential for human-to-human spread is crucial for estimating the infection rate accurately [3]. Moreover, the infection rate is not constant throughout an outbreak and can vary over time. Factors such as changes in population density, healthcare infrastructure, and public health interventions can affect the rate of transmission. Monitoring and analyzing these fluctuations are crucial for implementing timely and effective control measures.

Identification of infection sources: Tracing the origins

Identifying the source of infection is vital for understanding how emerging infectious diseases spread and for implementing targeted control strategies. Investigating the origin helps determine the initial cases, track the transmission pathways, and identify potential reservoirs or intermediate hosts.

For zoonotic diseases, which originate in animals and then infect humans, identifying the infection source becomes even more critical [4]. Diseases like Ebola, SARS, and COVID-19 are believed to have originated from animal reservoirs, highlighting the importance of conducting epidemiological investigations to identify and control potential spillover events.

Accurate identification of infection sources enables the implementation of preventive measures, such as culling infected animals, imposing trade restrictions, or implementing vaccination programs in high-risk areas. Furthermore, understanding the source

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helps in enhancing surveillance systems to detect future outbreaks and develop early warning systems [5].

Prevention and control strategies

For infectious diseases considered tropical, such as malaria, socio-economic factors may be much more important than climate. The effects of disease may also be a vicious circle where the diseases are poverty-promoting, making the poor even poorer, and in turn even more prone to diseases. Arboviruses especially have a tendency to affect poor people disproportionally and cause long-lasting sequelae, causing a burden for both families and societies. The effects of many diseases may also be directly incapacitating, which cause people lacking health care, to lay sick during the viraemic or parasitaemic phases, rendering them more prone to further vector bites and causing increased infection rates in the vectors [6].

Infectious diseases cause not only suffering and death, but also severe economic implications, which are not always immediately appreciated. Infection Rate Management: Implementing non-pharmaceutical interventions (NPIs) such as social distancing, wearing masks, and promoting hand hygiene can significantly reduce the infection rate. Timely implementation of these measures, based on accurate estimation of the R0, can help flatten the transmission curve and prevent healthcare systems from becoming overwhelmed.

Establishing robust surveillance systems for early detection of emerging infectious diseases is crucial. Rapid diagnostic tests, efficient contact tracing, and prompt reporting of suspected cases facilitate timely intervention and reduce the potential for further spread [7].

Enhanced Epidemiological Investigations: Strengthening the capacity for conducting thorough epidemiological investigations plays a pivotal role in identifying the infection sources and transmission routes. Collaborative efforts between human and animal health sectors can help uncover zoonotic diseases' origins and prevent future outbreaks.

Research and Innovation: Continuous research on emerging infectious diseases, including their transmission dynamics and development of vaccines or therapeutics, is essential. Investment in research and development can help enhance our understanding of these diseases, leading to improved prevention, control, and preparedness measures [8].

Pathogens

The EID that have received most publicity during the last decades have been viruses. Notable examples have been HIV, SARS, and Ebola. It is estimated that 44% of the diseases considered emerging in humans are viral.

RNA viruses are prone to emergence because of their rapid replication and high mutation rates, with around one misreading per replication, and large viral populations. However, the increased evolutionary pressure of having to adapt to both invertebrate and vertebrate hosts creates a lower rate of mutation in vector-borne viruses, and most of their mutations are synonymous.

Apart from point mutations, viruses can evolve through recombination events, especially among segmented viruses. The reassortment that occurs in influenza viruses is one example of this whereby influenza viruses create new combinations of genes. Single-stranded viruses may also recombine when different viral strains circulate in the same area, and occasionally infect the same cell [9], as in the example of Japanese encephalitis virus. However, in spite of the increased tendency for recombinations among segmented viruses, single-stranded RNA viruses seem to be overrepresented among emerging pathogens.

One of the most alarming phenomena in bacteria is the spread of antibiotic resistance. Although bacteria have a continuous evolution with mutations, they also have means of spreading their genetic material laterally between species through interchange of plasmids or integrons [10]. This capacity to share genetic material is not a phenomenon restricted to antibiotic resistance but an efficient way of handling different adverse environmental circumstances in nature as well. In the same manner, lateral transfer may occur of virulence genes, and integration of toxin gene elements from phages seems to commonly occur in Escherichia coli, although the toxins are not always expressed to the same amount.

Most studies seem to show that the acquisition of antimicrobial resistance genes in bacteria do cause a comparative disadvantage compared with non-resistant bacteria in the absence of antibiotics, but studies of some genes have shown no difference, or even the opposite. A longer evolution together with a resistance gene may lower the costs for the bacteria.

Fungi Fungal infections are emerging not only among plants, where they have long been an important cause of losses, but also among fishes, corals, amphibians, bats, and humans. In fact, fungal infections are contributing to the majority of extinction events that are known to have been caused by infectious diseases. This may be because fungi may effectively infect 100% of a population, before it is killed by the high mortality. Many fungi further have the possibility to persist as free-living spores [11].

Routes of transmission

Infections transmitted directly between individuals are dependent on the contact rate between susceptible and infectious people, and thus subsequently on the population density and the mixing of populations. Direct transmission of zoonotic diseases requires contact between animal hosts and humans, as in the case of rabies transmission, but transmission can also occur in the other direction. Close contact increases risk of transmission from pets or livestock to their owners, and the growing demands for exotic pets with subsequent increased trade further increases risk for introduction of new pathogens. Food- and water-borne pathogens are the major contribution to the billions of annual diarrhoea cases that occur [12]. Increases in food-borne transmission may be an effect of the difficulties in handling the manure from animal production safely, as this can be a source of many zoonotic pathogens. This is an issue both for small-scale farming where there may be no systems to handle manure at all, and in industrialized systems where the sheer amount of manure produced daily causes management problems. In addition, increasing water scarcity and water pollution in the future may cause increased risks for decreased food safety.

Conclusion

Infection rate and identification of infection sources are fundamental in comprehending the transmission dynamics of emerging infectious diseases. Accurate estimation of the infection rate helps assess the disease's potential impact and aids in implementing appropriate control measures. Concurrently, identifying the source of infection enables the development of targeted interventions to prevent further spread and enhance preparedness. By integrating these two factors into public health strategies, we can effectively mitigate the risks posed by emerging infectious diseases and safeguard global health. In spite of the knowledge that exists on EID, there are still gaps in the understanding of ecosystem disease regulation and how human actions may affect disease indirectly and in the long term. A multidisciplinary approach is needed, both in research and in policymaking. It is necessary to understand that although humans are depending on nature's ecosystems for our wellbeing, the different priorities of people and cultures necessitate compromises and trade-offs to be done. Top-down interventions may be counterproductive if the incentives of the local populations are not fully understand, and control measures may be devastating for the public health if the disease epidemiology is not fully grasped. Thus, disease control and monitoring is no longer to be considered a science of medicine and epidemiology alone, but also must include the social, environmental, and economic values appreciated by people and societies.

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