International Journal of Mathematical Analysis and Modelling

(Formerly Journal of the Nigerian Society for Mathematical Biology)

Volume 6, Issue 2 (Oct.-Nov.), 2023

ISSN (Print): 2682 - 5694
ISSN (Online): 2682 - 5708

Re-emergence of Lassa fever disease: the theory of interepidemic effect in action

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Abstract

The Lassa fever virus is one of several viruses that are likely to cause a future epidemic as reported by WHO due to re-emergence. The re-emergence of Lassa fever is due to the phenomenon called interepidemic effect. According to the current status of the interepidemic effect, any public health control measure taken to reduce the basic reproduction number will definitely make the disease to take a very long time to re-emerge. This short expository note establishes the fact that the re-emergence of Lassa fever disease is actually the theory of interepidemic effect in action.

Keywords: Lassa fever; mathematical modeling; interepidemic effect

1 Introduction

Lassa fever (LF) is a serious and potentially deadly viral disease caused by Lassa virus (LASV) that is prevalent in West Africa including Benin, Sierra Leone, Guinea, Liberia, Mali, and Nigeria because LASV reservoir and vector (Mastomys natalensis) is abundantly seen in these areas [6]. LASV has 2-21 day or more than that incubation period, thus its increases the risk of its transmission from endemic to non-endemic regions [13]. One of the major concerns with LASV is its high case fatality rate, additionally, the virus can easily spread from human-human contact, which makes it even more dangerous. Another major concern with LASV is the lack of effective vaccines and therapeutics for treating the disease. This is further compounded by the fact that the virus can also spread through aerosol, making it even more difficult to contain [3].

Due to the severe nature of LASV and its potential to spread easily, it is classified as a Biosafety Level 4 agent. This means that it is considered to be one of the most dangerous pathogens known to mankind. Despite this, the overall impact of LASV on the increased threat of viral diseases in West Africa has not been fully understood [2]. However, it is known that LASV is a significant cause of yearly morbidity and mortality in many of Africa's poverty-stricken communities such as during 2022 in Nigeria around 189 deaths reported out of 1067 confirmed cases of LASV. Annually, around 1–3 million infections occur of LF with around 5000 deaths [11].

Lassa virus is a public health security issue. Currently, there is no specific vaccine to prevent from Lassa fever. The antiviral drug ribavirin is used to treat the LF but it is not too much effective. However, researchers are working on developing a vaccine that would provide immunity against the

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virus. One approach being explored is to use a live attenuated version of the virus, which has been genetically modified to be less virulent. Another approach being studied is the use of a subunit vaccine, which consists of pieces of the virus that are able to stimulate an immune response but do not cause illness [7, 2].

Researchers should develop more sensitive and specific diagnostic tools as well as the development of point-of-care diagnostic devices that can be used in resource-limited settings [8]. The development of new antiviral drugs and understanding the epidemiology of Lassa fever is also crucial for controlling and preventing outbreaks. This includes identifying the main vectors and reservoirs of the virus, as well as understanding the risk factors that contribute to the spread of the disease. The Governments of endemic regions should arrange community education and awareness programs to individuals living in or traveling to areas where Lassa fever is endemic should take precautions to avoid contact with infected rats and practice good hygiene to prevent person-to-person transmission of the virus [1].

The incorporation of mathematical and theoretical reasoning into epidemiology, however, has been one of the field's most significant advancements. It is also a superb illustration of how mathematics can be used in practical situations. Lassa fever control is still a problem that needs mathematical answers on a global scale. The current application of mathematical modeling has found interesting new applications in epidemiology [4]. By mathematical model we mean a mathematical representation of a system that can be used to explore its behaviour. A mathematical model is a description of a system using mathematical concepts and language. Mathematical models can help public health epidemiologists understand the spread of disease, and evaluate the potential effectiveness of different control measures to be used based on mathematical analysis [10].

In recent times, several mathematical models have been formulated and analyzed in the literature to study the transmission and spread of Lassa fever. Motivated by the previous studies, [10] presented a novel mathematical model of Lassa fever that takes into account all the transmission modes (rodent-human, human-human and aerosol transmission) of the disease. They proposed that the spread of LF infection should depend on the number of susceptible, exposed, infective and recovered coupled with SIR model for rodent dynamics. Their model accounted for all the known transmission routes of LF disease in humans. They suggested a mass action law for the rate of new infections, and this idea has been basic in compartmental models since late nineteenth century. For the Obasi-Mbah model, it is easy to verify that the basic reproduction number denoted by R_0, is given as:

$$R_0 = \frac{\beta_2 \kappa \varepsilon \Lambda_h}{\mu_h (\kappa + \mu_h)(\phi + \mu_h + \delta)} + \frac{\beta_3 \vartheta \rho \Lambda_r}{\mu_r (\omega + \mu_r)}, \tag{1}$$

accounting for the human transmission and rodent transmission, respectively. The explicit definition of R_0 is that it is the expected number of disease cases produced by a typical infected individual in a wholly susceptible population over the full course of the infectious period. Based on the parameter values obtained by NCDC, the estimated value of R_0 ranges between 1.02 to 13.6 in Nigeria with negligible contribution of aerosol transmission [10]. On average, the geometric mean (GM) between these two extreme numbers is given as:

$$\begin{aligned} GM &= \sqrt{1.02 \times 13.6} \approx 3.7 \\ \therefore\ \mathrm{R}_0 &\approx 3.7 \end{aligned} \tag{2}$$

This goes to show that Nigeria is still an endemic region for Lassa fever disease. Re-emerging diseases are diseases that reappear after they have been on a significant decline. Re-emergence may happen because of a breakdown in public health measures for diseases that were once under control. They can also happen when new strains of known disease-causing organisms appear. Human behaviour affects re-emergence. More importantly, it is believed that re-emergence of infectious diseases is due to the phenomenon called interepidemic effect [10].

2 The theory of interepidemic effect

In 2019, Obasi and Mbah derived the inverse-square relationship between the basic reproduction number and interepidemic period of infectious disease, now referred to as Interepidemic Effect [10]. This is a feature of effective epidemic control measure. The basic reproduction number is used to measure the transmission potential of a disease. By basic reproduction number we mean the expected number of disease cases produced by a typical infected individual in a wholly susceptible population over the full course of the infectious period [5]. The goal of infectious-disease intervention is reducing the basic reproduction number to below one, because such a value means that new infections are in decline and will eventually reach zero. Interepidemic period of disease means occurring between epidemics of disease. In unforced susceptible, exposed, infectious, recovered (SEIR) models of directly transmitted diseases, incidence is predicted to exhibit damped oscillations with an approximate interepidemic period (T) [10]:

$$T = 2\pi\sqrt{AD} \tag{3}$$

where A is the average age of first infection, D is the sum of latent interval and the infectious interval of the disease. Recall that the average age of first infection, A is inversely related with the basic reproduction number, R_0 [9].

$$\begin{aligned} &A = \frac{\kappa_1}{R_0} \\ &\Rightarrow \frac{T^2}{4\pi^2} = AD = \frac{\kappa_1 D}{R_0} \Rightarrow T^2 R_0 = 4\pi^2 \kappa_1 D = \kappa_2 \\ &\Rightarrow R_0 = \frac{\kappa_2}{T^2} \Rightarrow R_0 \propto \frac{1}{T^2} \end{aligned} \tag{4}$$

This indicates that the basic reproduction number is inversely proportional to the square of inter-epidemic period of an infectious disease. This implies that increase in R_0 would decreased T^2 . This is illustrated in Table 1 as well as in Figure 1 below using the hypothetical data for the basic reproduction number.

Table 1: Estimation of parameters in interepidemic effect

R_0	k_0	T^2	T	$(1/T)^2$
1.02	3	2.941	1.714934	0.34
2.52	3	1.19	1.090871	0.84
4.02	3	0.746	0.863713	1.34
5.52	3	0.543	0.736885	1.842
7.02	3	0.427	0.653452	2.342
8.52	3	0.352	0.593296	2.841
10.02	3	0.299	0.546809	3.344
11.52	3	0.26	0.509902	3.846
13.02	3	0.23	0.479583	4.348
14.52	3	0.207	0.454973	4.831
16.02	3	0.187	0.432435	5.348

Source: Author's computation (2023)

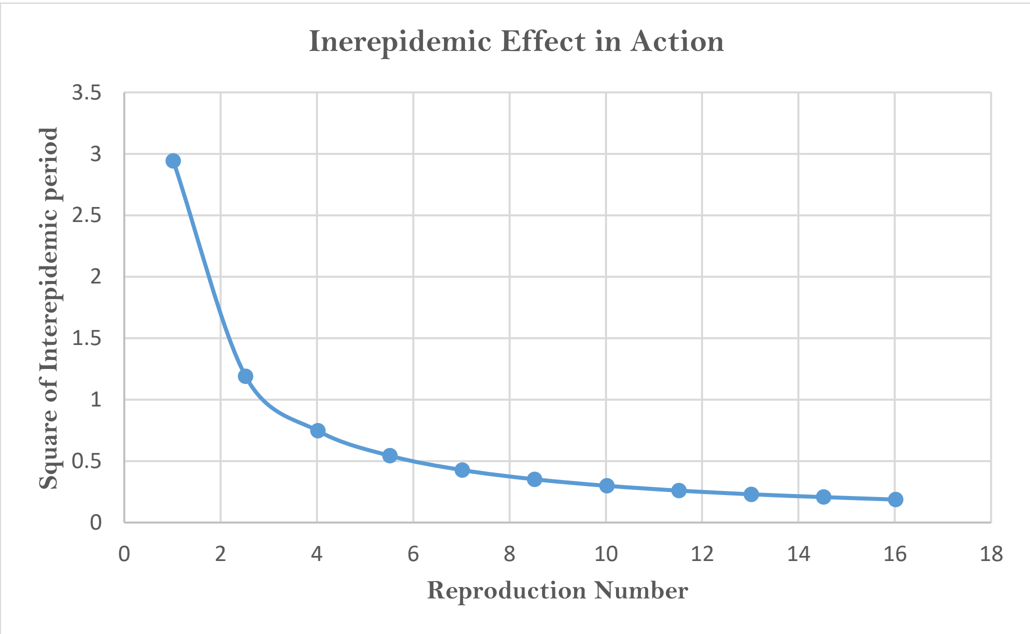

Figure 1: Plot of interepidemic effect in action

Figure 1 shows the relationship describing interepidemic effect. It means that, any public health policy or measures taken to reduce the basic reproduction number will definitely make the disease to take a very long time to re-emerge [10]. This by implication goes to show that introduction of effective control measures will lead to a very long time for the re-emergence of infectious disease. This is a feature of effective epidemic control measure now referred to as interepidemic effect. The interepidemic effect shows that the basic reproduction number in epidemic theory is essentially an important measure used in infectious disease control, immunization and eradication programmes. It should also make you think about what we really mean by the effective control measure. This corroborates the assertion that re-emergence of infectious diseases may happen because of a breakdown in public health measures for diseases that were once under control.

In the interepidemic effect, re-emergence of an infectious disease depends on the effectiveness of the control measures. This goes to show that to achieve sustainable disease control, NCDC is to be aware of the importance of this effect, which in turn helps to achieve Sustainable Development Goals 3 [12]. It is therefore one of the phenomena proving the existence of sustainable disease control. This is a fundamental result in mathematical epidemiology that addresses the issue of re-emergence of infectious diseases. Recall that re-emerging infectious diseases are diseases that once were major health problems globally or in a particular country, and then declined dramatically, but are again becoming health problems for a significant proportion of the population (Lassa fever, malaria and tuberculosis are examples). Among other factors, interepidemic effect has contributed to the understanding of emergence and re-emergence of infectious diseases. This implies that interepidemic effect is used in achieving sustainable control of infectious diseases. Therefore, there should be policy development by NCDC to implement the theory of interepidemic effect. However, this short expository note establishes the fact that the re-emergence of Lassa fever disease is actually the theory of interepidemic effect in action.

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