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Predicting the Evolution of the 2013 H7N9 Epidemic in China

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On March 31, 2013, the Chinese government notified the World Health Organization (WHO) of three influenza A(H7N9) cases, including two deaths. Since then, the number of notified cases has increased, reaching 63 cases (including 14 deaths) as of April 16. WHO Disease Outbreak News (<http://www.who.int/csr/don/en/index.html>) made the data public in a timely manner.

Monitoring the log-log plot of the cumulative number of patients (X) versus that of deaths (Y) is useful for predicting the evolution of an epidemic. The plot is expressed as $\log Y = k(\log X - \log N_0)$, where k is a constant and N_0 is the value of X at the intersection of the plot line and X axis. If the case-fatality rate remains constant, k equals 1 and N_0 is the inverse of the mortality rate. In case of the influenza 2009 H1N1 epidemic in Mexico, where the epidemic originated, k was not 1 but 0.65 and N_0 4–5, i.e., the case-fatality rate continuously decreased (1). However, for a given pair of pathogen and host, the case-fatality rate should have remained constant. This paradox was explained by postulating two viral populations, one with higher virulence and of a lower propagation rate (HVV) and the other with lower virulence and a higher propagation rate (LVV) (2,3). These premises are reasonable because the influenza virus mutates at high frequency and once mutants with lower virulence and higher chance of propagation appear, they can easily predominate.

An example of simulation based on these considera-

tions is shown in Table 1. The following numerical premises were used:

1. The current epidemic consists of the original H7N9 with a case-fatality rate of 50% (HVV) and the H7N9 mutant with a case-fatality rate of 0.1% (LVV); and
2. LVV is transmitted five-fold quicker than HVV. This premise is reasonable because people infected with HVV will be bedridden, while those infected with LVV will remain active and have a higher chance of transmitting the virus.

Fig. 1A shows the log-log case-fatality plot for H7N9 that originated in China. The slope was approximately $k = 0.66$, and N_0 was almost 1. Fig. 1B shows co-plots of the H7N9 epidemic and the plot simulated using Table 1. The two plots are almost overlapping.

If the simulation is correct, the mutants with low virulence and a higher propagation rate, i.e., LVV, appeared at time t_2 with 9 patients and 4 deaths. It approximately corresponds to April 4 when 11 patients and 5 deaths were reported to WHO. If the above reasoning is correct, the consequence will be quite like that of influenza 2009 H1N1 pandemic that originated in Mexico.

While it may be difficult to stop the circulation of the attenuated strains, the circulation of strains with higher virulence should be prevented by increasing the level of vigilance and intensifying preventive measures.

Note: One caution concerning the simulation is that the given solution is not unique because it was obtained

Table 1. Simulation of influenza epidemic consisting of two viral populations with different virulence

Time	HVV		LVV		HVV [$f = 8/9$; $D = 2$; $M = 1/2$], LVV [$f = 1/9$; $D = 10$; $M = 1/1000$]	
	Patient	Death	Patient	Death	Patient (HVV + LVV)	Death (HVV + LVV)
t1	4	2	0	0	4	2
t2	8	4	1	0	9	4
t3	16	8	10	0	26	8
t4	32	16	100	0	132	16
t5	64	32	1000	1	1064	33

t1–t5: time elapsed from the start of the epidemic (t1) to time t5.

HVV: highly virulent virus with a case-fatality rate of 1/2.

LVV: lowly virulent virus with a case-fatality rate of 1/1000.

The rightmost columns, HVV [$f = 8/9$; $D = 2$; $M = 1/2$], LVV [$f = 1/9$; $D = 10$; $M = 1/1000$] (3), are the total number that added a number of HVV and LVV.

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Fig. 1. Log-log plot of the cumulative number of cases versus that of deaths for influenza A(H7N9) in China in 2013. The data used were summary data reported by the WHO regarding each issue of Disease Outbreak News. Although the WHO information included the date and site of the cases and deaths, they were not always complete, particularly with regard to correspondence between cases and deaths. Therefore, to maintain consistency, the detailed information was not used. However, because the plot is that of cumulative numbers, the above mentioned plot and the plot with more detailed information will be essentially the same. (A) Log-log plot of cases (X axis) versus deaths (Y axis) for A(H7N9) influenza in China. The first (left most) plot is for March 31 (April 1 issue of WHO Disease Outbreak News) and the last plot is for April 16, 2013 (closed diamonds). See note added in proof for open diamonds. (B) Co-plots of A(H7N9) influenza in China (closed diamonds) and simulated epidemic in Table 1 (open squares).

by trial and error. By manipulating and balancing three parameters, i.e., the speed of viral spread, mortality rate for the given virus-host pairs, and ratio of LVV and HVV at the start of the epidemic, other similar plots can be obtained. Refer to the previous paper (3) for details.

Note added in proof Plots in open diamonds in Fig. 1A are data provided by WHO after submission of this paper. The last plot is for May 17, 2013. The abrupt rise of the curve towards the end of the plot is observed when the reporting of patients stopped either due to arrest of further virus propagation or to cessation of reporting on account of further attenuation of the circulating virus.

Conflict of interest None to declare.

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