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Perspective

# Quantification of the severity of an outbreak in human infection control

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SUMMARY

*Background:* The severity of an outbreak is a priority in decision-making for human infection control. However, there have been no reports on how to quantify the severity of an outbreak.
*Methods:* We propose a simple method to measure the severity of an infectious disease outbreak. It involves scoring the severity of clinical signs, the transmission of the infection, the number of cases, and the infection source.
*Results:* The method was evaluated using the data available at the early stage of some recent outbreaks of infectious diseases, including the influenza A (H1N1) pandemic in 2009, and the evaluation supports the design idea.
*Conclusion:* The method is practical for rating the severity of an infectious disease outbreak, though it should be optimized. It could also be used to judge whether an event constitutes a public health emergency of international concern (PHEIC) or not.

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## 1. Introduction

Decisions on whether or not to instigate emergency measures to control an outbreak of an infectious disease usually rely on the identification of the pathogen. However, the 'golden time' for infection control could be lost because pathogen identification may be time-consuming or even wrong, especially for some new emerging infectious diseases. Severe acute respiratory syndrome (SARS) is a good example.[1,2] The first human case of SARS occurred in November 2002 in Guangdong, China. By February 9, 2003, 305 cases of SARS with five fatalities had been reported in Guangdong, and its transmission among people without close contact was likely. Emergency measures such as isolation of patients and movement restrictions were not implemented until the pathogen was correctly identified in March 2003. As a result, the outbreak finally spread to approximately 30 countries with more than 8000 probable cases and 800 fatalities (www.who.int/csr/sars/en/). The outbreak of Nipah virus in Malaysia is another good example.[3,4] It started in September 1998 in the village of Ampang in the Kinta district, where several cases of fatal febrile encephalitis in humans followed respiratory and encephalitic diseases in pigs. By March 6,

1999, the number of human encephalitis cases had increased to 79 at an accelerated rate, with a high fatality (>40%). The outbreak was linked to diseased pigs and was initially incorrectly diagnosed as Japanese encephalitis. Emergency measures were not implemented until the pathogen was correctly identified as the Nipah virus on March 19, 1999. As a result, the outbreak involved 265 human cases with 115 fatalities and the culling of more than 1 million pigs.[3]

In addition, important emergency measures may sometimes not be implemented to control a severe outbreak because the pathogen is assumed to be empirically or legally not serious. The *Streptococcus suis* crisis in 2005 in China is a case in point.[5] It began in a region of Sichuan Province with a dozen cases with severe clinical signs between July 12 and July 21, 2005. Up until July 24, 2005, 58 cases with 17 fatalities were reported, and the outbreak was linked to diseased pigs. No evidence of human-to-human transmission was found. Two days later, the pathogen was identified as *Streptococcus suis*, and emergency measures such as hygiene education, pig vaccination, and proper disposal of dead pigs, were implemented. However, culling of the infected or possibly infected pigs was not implemented because the pathogen is usually assumed not to be that serious. Consequently, the outbreak was protracted, lasting until to the end of August 2005 with 157 more cases and 20 more fatalities (China's official website, www.xinhuanet.com).

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**Table 1**
Scoring of four aspects for the evaluation of the severity of a disease outbreak

| Aspect | Description | Score |
|---|---|---|
| Clinical signs | Mild, usually requiring treatment without hospitalization | 2 |
| | Severe, usually requiring hospitalization, but without severe outcomes like death, abortion, or body abnormality | 3 |
| | Severe, <10% cases having developed severe outcomes like death, abortion, or body abnormality | 4 |
| | Very severe, 10–20% cases having developed severe outcomes like death, abortion, or body abnormality | 5 |
| | Highly severe, >20% cases having developed severe outcomes like death, abortion, or body abnormality | 6 |
| Transmission | No evidence supporting person-to-person transmission | 1 |
| | Transmission through special behaviors such as sex is probable | 2 |
| | Transmission among frequent close contacts is probable | 3 |
| | Transmission among casual close contacts is probable | 4 |
| | Transmission among people without close contact is probable | 5 |
| Number of cases | 1–9 | 1 |
| | 10–50 | 2 |
| | 51–100 | 3 |
| | 101–200 | 4 |
| | >200 | 5 |
| Infection source[a] | Without links to domestic animals | 1 |
| | With a possible link to domestic animals | 2 |
| | With clear evidence to support domestic animals as an infection source | 3 |

[a] If the infection is from domestic animals, the infected animals should pose a threat to people. In addition, emergency mass surveillance, vaccination, and culling of domestic animals, which are difficult and of economic significance, may have to be implemented to control the human outbreak. Therefore, the infection source is considered in this scoring system.

Therefore, to control a severe outbreak of infectious disease in time, emergency measures should be implemented as soon as possible if the outbreak is known to be serious, no matter what the pathogen is. This concept appears rational because some effective emergency measures, such as isolation of patients, movement restriction of close contacts, travel alerts, case reporting, extensive disinfection, and eliminating the possible infection sources, could be implemented before the identification of the pathogen. However, currently no method has been formulated to rate the severity of an outbreak of a human infectious disease. In effect, it is difficult to evaluate the severity of an outbreak rationally and practically, especially at the early stage of the outbreak. The word 'rationally' requires us to consider multiple aspects of the outbreak, including clinical signs and outcomes, transmission rate and numbers of cases, while the word 'practically' means the evaluation should be easy to understand and operate.

Here, we report a seemingly rational and practical method, carefully designed to measure the severity of an outbreak of infectious disease, which could be the prototype of a future standardization.

## 2. The method

The method involves respectively scoring the severity of clinical signs, transmission of the infection, number of cases, and the infection source (Table 1). The scores of the four aspects of an outbreak are multiplied together and the resulting product represents the severity of the outbreak. A higher product indicates a more serious outbreak, with products in the ranges of 1–14, 15–29, 30–59, 60–119, 120–200, 200–450 rating the severity of the outbreak as grade I, grade II, grade III, grade IV, grade V, and grade VI, respectively. For example, if a total of 27 people are infected in an outbreak with mild clinical signs, likely with transmission among frequent close contacts, and the outbreak is linked to sheep (though no clear evidence has been found), the final score of the outbreak is 24 (= 2 × 3 × 2 × 2), which suggests the outbreak is of grade II severity.

In the method, a case is defined as a person suspected to be infected with the same known or unknown pathogen by a medical professional entity, like a hospital, a medical research institute, or the health section of the local government.

Generally speaking, grade I, grade II, grade III, grade IV, grade V, and grade VI indicate that the outbreak is mild, moderate, severe, very severe, highly severe, and extremely severe. Moreover, if an outbreak is rated grade III (severe), it is assumed to be a public health emergency of international concern (PHEIC), and should be reported to the World Health Organization (WHO), according to the new International Health Regulations adopted in 2005.[6]

## 3. Explanation and discussion

In epidemiology, the four aspects (severity of clinical signs, transmission of the infection, number of cases, and infection source) largely determine the severity of the future development of an outbreak if no emergency measures are implemented to control the outbreak. Crude (not exact) data on these four aspects required by the method are usually available at the early stages of an outbreak, provided it has aroused the concerns of a medical professional entity. Therefore, the method is practical.

In total there are 375 combinations of the four aspects in this evaluation system, and the evaluation results of these 375 combinations largely support the design idea that a higher score product indicates a more serious outbreak.

The method does not directly consider other aspects including the basic reproduction rate, the generation time, and age distribution. These aspects actually overlap with the aforementioned four aspects, or they have little impact on the future development of an outbreak.

Using this method, the human outbreaks of SARS virus, Nipah virus, and Streptococcus suis described above would be rated as grade IV (very severe), grade III (severe) and grade III (severe), respectively, at their early stages, according to the data given in the Introduction (Table 2). Based on the data published by the WHO on April 24, 2009, the infection with the influenza A (H1N1) virus in Mexico would be scored as 120 and rated as grade IV (Table 2).

Like the rating of an earthquake in seismology, the quantitative evaluation of the severity of an outbreak of a human infectious disease should be important in infection control, especially for emerging infectious diseases. It allows awareness of the exact severity of an outbreak of infectious disease using the same rule. It could also be used to determine what measures should be implemented to control an outbreak of infectious disease and whether the outbreak should be reported and controlled locally, nationally, or internationally, no matter whether the pathogen has been identified or not. According to the new International Health Regulations adopted in 2005, all events that may constitute a

**Table 2**
Evaluation of the severity of four outbreaks of human infectious disease in the early stage

|  | SARS virus | Nipah virus | Streptococcus suis | Influenza A (H1N1) virus[a] |
|---|---|---|---|---|
| Affected country | China | Malaysia | China | Mexico |
| Date for evaluation | February 9, 2003 | March 6, 1999 | July 24, 2005 | April 24, 2009 |
| Score for clinical signs | 4 | 6 | 6 | 4 |
| Score for transmission | 4 | 1 | 1 | 4 |
| Score for number of cases | 5 | 3 | 3 | 5 |
| Score for infection source | 2 | 2 | 1 | 2 |
| Product of the scores | $4 \times 4 \times 5 \times 1 = 80$ | $6 \times 1 \times 3 \times 2 = 36$ | $6 \times 1 \times 3 \times 2 = 36$ | $4 \times 4 \times 5 \times 2 = 160$ |
| Grade | IV | III | III | IV |

SARS, severe acute respiratory syndrome.

[a] The calculation was based on the data published by the WHO on April 24, 2009, which stated, "the number of cases has risen steadily through April and as of 23 April there are now more than 854 cases of pneumonia from the capital. Of those, 59 have died." Therefore, the score of clinical signs is 4. In addition, of the Mexican cases, 18 were laboratory-confirmed in Canada as swine influenza A (H1N1), while 12 of these were genetically identical to the swine influenza A (H1N1) viruses from California. This shows a possible link between the outbreak and pigs, obtained from pathogen sequences, though no laboratory data were available to support the link.

PHEIC should be reported to the WHO. However, how to define PHEIC in a practical way remains difficult (www.who.int/entity/csr/ihr/en/). The above evaluation method should be helpful to judge whether the outbreak of an infectious disease is of PHEIC or not, at least when its pathogen has not been identified.

Unlike the degree of severity of an earthquake, the severity of an outbreak of infectious disease is dynamic. It may be rated grade I (mild) at the beginning, but when more cases emerge and more characteristics of the outbreak are known later, the outbreak could be re-evaluated as grade II (moderate) or higher. An outbreak may also be rated grade V (severe) at the beginning, but when more data are available to clarify some aspects, the outbreak could be re-evaluated as grade II (moderate). For example, with the exact data available in April–June, 2009, the severity of the human influenza A (H1N1) pandemic would initially have been rated as grade V (highly severe), and could have been rated as grade III (severe) on July 1, 2009, because the clinical signs of the infections were then considered mild and the possible link of the infections to domestic animals were excluded .

We recognize that there is great uncertainty as to whether the method will actually do what is desired. The method allows for others to tailor it through the addition of new parameters or by adjusting the scoring system. As, we assume, the first method on this important issue, it will spark discussion among public health experts and provide a candidate prototype for future standardization.

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