

Both in vitro and in vivo animal and human studies demonstrate age-related declines in both humeral and cellular components of the immune system (9). In old (23 months) mice, the normal functioning of follicular dendritic cells appears to be strongly impaired when compared with young mice (10); according to researchers, "Antigen transport was defective and only a small fraction of antigen transport sites developed." (10). Furthermore, follicular dendritic cells were ultrastructurally atrophic, retained little antigen, and produced no iccosomes. By interfering with normal follicular dendritic cell function, age likely has the same effect on transmissible spongiform encephalopathies as has been observed due to dedifferentiation of follicular dendritic cells (8). Senescence of the immune system function could interfere with transmissible spongiform encephalopathy pathogenesis in other ways as well, such as impairing migrating intestinal dendritic cells or complement pathways involved in complexing PrP^{Res} to follicular dendritic cells.

This hypothesis could be readily tested by intracerebral versus peripheral PrP^{Res} challenge of young versus old animals. Because the intracerebral challenge bypasses the immune system portal, old, peripherally challenged animals should show a disproportionate reduction in disease risk if immune system senescence is important in regulating pathogenesis.

Dennis M. Heisey*
and **Damien O. Joly†**

*United States Geological Survey, Madison, Wisconsin, USA; and †University of Wisconsin, Madison, Wisconsin, USA

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Address for correspondence: Dennis M. Heisey, USGS-National Wildlife Health Center, 6006 Schroeder Road, Madison, WI 53711, USA; fax: 608-270-2415; email: dheisey@usgs.gov

SARS Epidemiology Modeling

To the Editor: To assess the effectiveness of intervention measures during the recent severe acute respiratory syndrome (SARS) pandemic, Zhou and Yan (1) used Richards model, a logistic-type model, to fit the cumulative number of SARS cases reported daily in Singapore, Hong Kong, and Beijing. The key to using mathemati-

cal models for SARS epidemiology is understanding the models (2). In the Richards model (1), the function $F(S)$ in the model was described as measuring "the effectiveness of intervention measures." The parameters in $F(S)$, namely, the maximum cases load K and the exponent of deviation a , depict the actual progression of the epidemic as described by the reported data. In other words, the parameter estimates are used to quantify end results of the intervention measures implemented during the outbreaks. Simply put, the all-important question of "what if?" was not answered by their result. To gauge the effectiveness of intervention measures, one should consider a more complicated model with variable maximum case load and growth rate (r) that highlights the time-varying nature of an epidemic and its dependence on the intervention measures implemented during the epidemic.

Predicting the trend of an epidemic from limited data during early stages of the epidemic is often futile and sometimes misleading (3). Nevertheless, early prediction of the magnitude of an epidemic outbreak is immeasurably more important than retrospective studies. But how early is too early? Intuitively, the cumulative case curve will always be S-shaped and well-described by a logistic-type model. The essential factor is the time when the inflection of the cumulative case curve occurs, i.e., the moment when a rapid increase in case numbers is replaced by a slower increase. Since the inflection point, approximated by t_m (1), dictates the point in time when the rate of increase of cumulative case numbers reaches its maximum, the moment marks the key turning point when the spread of the disease starts to decline. As long as the data include this inflection point and a time interval shortly after, the curve fitting and predicting future case number will be reasonably accurate.

To illustrate this point more pre-

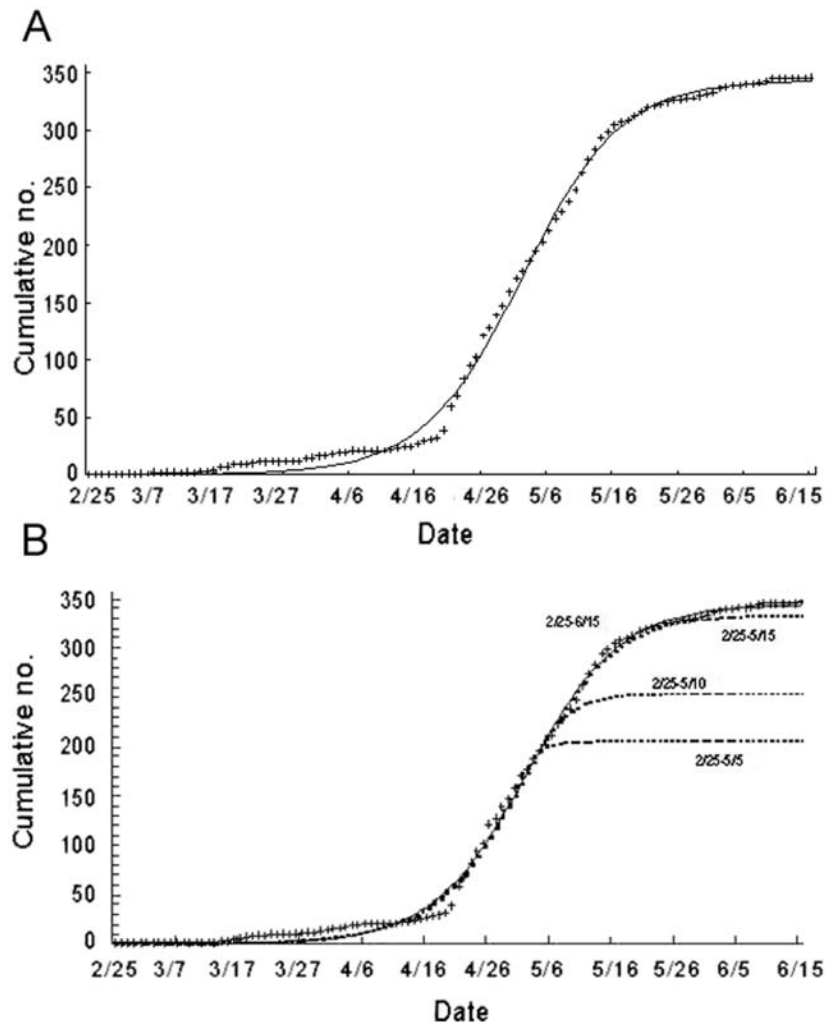


Figure. SARS cases, Taiwan 2003, Richards model; + = real data. A, confirmed cases; B, estimated cases using truncated data.

cisely, the cumulative SARS case data by onset date in Taiwan were obtained from the SARS databank of Taiwan Center for Disease Control. The data cover the time from February 25, 2003, the onset date of the first confirmed SARS case, to June 15, 2003, the onset date of the last confirmed case; a total of 346 SARS cases were confirmed during the 2003 outbreak in Taiwan (4). The cumulative case data are fitted to the cumulative case function $S(t)$ in Richards model with the initial time $t_0 = 0$ being February 25 and the initial case number $S_0 = S(0) = 1$. Description of the model, as well as the result of the parameter

estimation, is shown in the online Appendix (http://www.cdc.gov/ncidod/eid/vol10no6/03-1023_app.htm). The estimates for the parameters are $r = 0.136$ (95% confidence interval [CI] 0.121 to 0.150), $K = 343.4$ (95% CI 339.7 to 347.1), $a = 1.07$ (95% CI 0.80 to 1.35), and the approximate inflection point at $t_m = 66.62$ (95% CI 63.9 to 69.3) with adjusted $r^2 > 0.998$, $p < 0.0001$ for the goodness-of-fit of the model (Figure). The result indicates that the infection occurred on May 3, and the estimate for the maximum case number $K = 343.3$ is 0.8% off the actual total case numbers.

Moreover, the case number data

are sorted by onset date. Given a mean SARS incubation of 5 days (4–6 days) (5), the inflection point for SARS in Taiwan could be traced back to 5 days before May 3, namely April 28. On April 26, the first SARS patient in Taiwan died. Starting April 28, the government implemented a series of strict intervention measures, including household quarantine of all travelers from affected areas (6). In retrospect, April 28 was indeed the turning point of the SARS outbreak in Taiwan.

To address making projections during an ongoing epidemic, we used the same dataset but used various time intervals (all starting February 25) but truncated at various dates around the inflection point of May 3. The resulting parameter estimates are given in the Table of the online Appendix. For the truncated data ending on April 28 before the inflection, an unreasonable estimate of $K = 875.8$ was obtained. However, if we use the data ending on May 5, May 10, May 15, and May 20, we obtain estimates of $K = 204.9$, 253.1, 334.2, and 342.1, respectively. These estimates improve as we move further past the inflection time of May 3 (Figure). Moreover, the last estimate, using data from February 25–May 20 only, produces a 1.1% error from the eventual cumulative case number of 346, with 95% CI of 321.5 to 362.6. This retrospective exercise demonstrates that if the cumulative case data used for predictive purpose during an outbreak contain information on the inflection point and approximately 2 weeks afterwards, the estimate for the total case number can be obtained with accuracy, well before the date of the last reported case. This procedure may be immensely useful for deciding future public health policies although correctly determining the true inflection point during a real ongoing epidemic calls for scrutiny and judicious use of the model, as with all mathematical epidemic models.

**Ying-Hen Hsieh,* Jen-Yu Lee,*
and Hsiao-Ling Chang†**

*National Chung Hsing University, Taichung, Taiwan; and †Center for Disease Control, Taipei, Taiwan

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Address for correspondence: Ying-Hen Hsieh, Department of Applied Mathematics, National Chung Hsing University, 250 Kuo-Kuang Rd., Taichung, Taiwan 402; fax: 886-4-22853949; email: hsieh@amath.nchu.edu.tw

In Reply: Our analysis of the dynamics of reported severe acute respiratory syndrome (SARS) clinical cases was conducted in May 2003 during the height of the public panic (1). Our primary goal in that study was to predict “when the epidemic might be brought under control if the current intervention measures were continued.” (1). We used the Richards model and successfully predicted the epidemic cessation dates in Beijing, Hong Kong, and Singapore. Our predicted total number of SARS cases

was close to the actual number of cases. In addition, we estimated the basic reproductive rate (R_0) of SARS infection, and our estimates based on the deterministic model were similar to those based on stochastic models (2,3). Therefore, our analysis provided useful information on the epidemiologic characteristic of SARS infections in three major Asian cities.

Hsieh et al. (4) commented that our article did not address the effect that specific intervention measures might have on the dynamics of SARS infection. Our study was not intended to measure this. As we stated in our article, “the transmission mechanism of the coronavirus that causes SARS and the epidemiological determinants of spread of the virus are poorly understood.” Any models built on these unknowns are not suitable for assessing the effects of specific intervention measures. A method suggested by Hsieh et al. (4) to merely “consider a more complicated model with variable maximum case load and growth rate” will not answer the question to any extent.

The retrospective analysis of SARS case dynamics in Taiwan by Hsieh et al. (4) found that “as long as the data include this inflection point and time interval shortly after, the curve fitting and predicting future case number will be reasonably accurate.” This notion holds only if the true inflection point is known before an epidemic ends. The main difficulty is how the true inflection point is correctly determined, as noted by Hsieh

et al. (4). The time when inflection occurs varies tremendously if truncated data of cumulative SARS case numbers are used. To illustrate this point, we used the cumulative number of reported probable SARS cases in Hong Kong, starting March 17, 2003, but truncated at various dates, and calculated the date when inflection occurred (Table). For example, if the data period from the onset date (March 17, 2003) to the last case reported (June 12, 2003) was used, the date when inflection would occur was estimated as March 19, 2003. If the truncated data ending April 9, April 16, April 30, May 14, and May 28, 2003, were used, the dates when inflection would occur were estimated as April 2, February 7, March 3, March 23, and April 2, 2003, respectively (Table). Clearly, inflection point dates became a moving target as the epidemic progressed. When truncated data ending April 9, April 16, April 30, May 14, and May 28, 2003, were used, the corresponding estimated maximum numbers of cumulative cases (K) were 1,107, 1,907, 1,819, 1,749, and 1,733, respectively. Estimation of K improved when the data period used for prediction was at least one month past the March 19 inflection point obtained from the entire epidemic period. This analysis highlights the difficulty in identifying an optimal inflection point for prediction purposes during an ongoing epidemic when only a partial cumulative case number is available.

We fully agree with Hsieh et al. (4)

Table. Predicted inflection point and dates when inflection occurs based on truncated data of cumulative number of reported severe acute respiratory syndrome cases in Hong Kong

Data period (ending date)	t_m^a	Date ^b	K^c	r^d	α^e
April 9, 2003	16.62	April 2, 2003	1,107	0.20	0.74
April 16, 2003	-40.79	February 7, 2003	1,907	0.07	52.11
April 30, 2003	-13.52	March 3, 2003	1,819	0.07	10.21
May 14, 2003	6.80	March 23, 2003	1,749	0.09	2.84
May 28, 2003	17.31	April 2, 2003	1,733	0.10	1.38
June 12, 2003	2.63	March 19, 2003	1,751	0.09	3.77

^a t_m is the inflection point of the model.

^bDate refers to the date when inflection occurs.

^c K is the predicted maximum number of cumulative cases.

^d r is the intrinsic growth rate.

^e α measures the extent of deviation of S-shaped dynamics from the classic logistic growth curve.

that the quantitative assessment of the effectiveness of public health intervention measures for SARS is a difficult task for modelers. To make models useful for assessing the effects of specific intervention measures and for predicting the future dynamics during an ongoing epidemic, we need improved knowledge on the transmission mechanisms, pathogenesis, and the epidemiologic determinants of the spread of the virus. Any retrospective analysis of the 2003 SARS epidemic that improves our knowledge of SARS epidemiology is welcome.

Guofa Zhou* and Guiyan Yan*

*State University of New York, Buffalo, New York, USA

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Address for correspondence: Guofa Zhou, Department of Biological Sciences, State University of New York, Buffalo, NY 14260, USA; fax: 716-645-2975; email: gzhou2@buffalo.edu

Diagnostic Criteria during SARS Outbreak in Hong Kong

To the Editor: A novel coronavirus caused more than 8,000 proba-

ble cases of severe acute respiratory syndrome (SARS) worldwide (1,2) during the 2003 outbreak. Before the etiologic agent was identified, the diagnosis of SARS was made according to a set of clinical-epidemiologic criteria as suggested by the Centers for Disease Control and Prevention (CDC) (1–3). These criteria remained important in the initial diagnosis and prompt isolation of patients because the overall sensitivity of initial reverse transcriptase-polymerase chain reaction (RT-PCR) testing for SARS-associated coronavirus (SARS CoV) RNA on upper respiratory specimens ranged from approximately 60% to 70% (though sensitivity improved with a second test) (4,5). In a SARS screening clinic at the Prince of Wales emergency department, the positive predictive value (PPV) of these criteria was estimated to be 54% (95% CI 39% to 69%) (6). The relative importance of the clinical versus epidemiologic criteria had not been evaluated. By using paired serologic testing to determine SARS-CoV infection (3), we evaluated the relative importance of the clinical-epidemiologic diagnostic criteria during an outbreak.

Patients with a diagnosis of SARS, and who were admitted to one of five regional hospitals in Hong Kong for isolation and treatment from March 4 to June 6, 2003, were included in this retrospective analysis. Probable SARS case-patients were those who met the CDC clinical criteria for severe respiratory illness of unknown etiology (3), and met the epidemiologic criterion for exposure in either a close or a possible contact. Close contact was defined as caring for, living with, or having direct contact with body fluids of a probable SARS patient (e.g., working in the same medical ward or staying in the same household) within 10 days of initial symptoms. Because Hong Kong was the documented SARS transmission site from February 1 to July 11, 2003,

a modified epidemiologic criterion of possible contact was adopted. Possible contact was defined as staying or working in the same hospital compound, or residing in the same building where case clusters of SARS had been reported, within 10 days of symptoms onset.

Laboratory testing of paired immunoglobulin (Ig) G antibody to SARS-CoV was used to determine infection (7). Positive serologic evidence of infection was defined as a four-fold rise in antibody titer or detection of antibody in convalescent-phase serum. Seronegativity was defined as absence of antibody in convalescent-phase serum obtained ≥ 21 days after symptom onset (3). Seronegativity in this defined time frame (≥ 21 days – serum collected before July 11, 2003, and beyond 28 days) excluded the diagnosis of SARS (3). Samples from patients showing nonspecific fluorescent signals were considered negative for SARS-CoV infection. RT-PCR was performed on clinical specimens (respiratory, fecal) from all patients (1,3–5).

Demographic and laboratory parameters and history of close contact were compared between the seropositive and seronegative groups. Student *t* test was used to analyze continuous variables. A *p* value of <0.05 was considered statistically significant. Odds ratio (OR) and 95% confidence interval (CI) were calculated for categorical variables.

During the study period, 475 patients were hospitalized with probable SARS. One hundred patients were excluded because their serologic results were either missing ($n = 37$) or they died before day 21 of illness (no convalescent-phase serum, $n = 63$). Three hundred seventy-five patients were included in the analyses; 353 (94.1%) patients were serology-positive for SARS-CoV. Two hundred sixty-three of the 353 patients (74.5%) had a 4-fold increase in antibody titers, and 90 of the 353 patients