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Media coverage and hospital notifications: Correlation analysis and optimal media impact duration to manage a pandemic

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HIGHLIGHTS

- We develop functional relationships between the media impact and intensity of mass media coverage.
- The multiple correlation analyses show the strong relations between mass media and H1N1 outbreak .
- Nonlinear least squares estimation to identify the best-fit parameter values from the observed data.
- Uncertainty and sensitivity analyses determine key parameters during early phase of disease outbreak.
- Main results show that media publicity should be focused on how to guide people's behavioral changes.

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ABSTRACT

News reporting has the potential to modify a community's knowledge of emerging infectious diseases and affect peoples' attitudes and behavior. Here we developed a quantitative approach to evaluate the effects of media on such behavior. Statistically significant correlations between the number of new hospital notifications, during the 2009 A/H1N1 influenza epidemic in the Shaanxi province of China, and the number of daily news items added to eight major websites were found from Pearson correlation and cross-correlation analyses. We also proposed a novel model to examine the implication for transmission dynamics of these correlations. The model incorporated the media impact function into the intensity of infection, and enhanced the traditional epidemic SEIR model with the addition of media dynamics. We used a nonlinear least squares estimation to identify the best-fit parameter values in the model from the observed data. We also carried out the uncertainty and sensitivity analyses to determine key parameters during early phase of the disease outbreak for the final outcome of the outbreak with media impact. The findings confirm the importance of responses by individuals to the media reports, with behavior changes having important consequence for the emerging infectious disease control. Therefore, for mitigating emerging infectious diseases, media reports should be focused on how to guide people's behavioral changes, which are critical for limiting the spread of disease.

1. Introduction

In modern society, the interaction between mass media (television, radio, newspapers, billboards, and booklets) and emerging or re-emerging infectious diseases spread and control constitutes a complex and interconnected relationship. On one hand, the degree of mass media attention to a particular disease outbreak may be determined by the infection dynamics and informatics such as daily hospital notifications and disease relevant mortality; and on the other hand, mass media may be used to inform the public infection dynamics and enforce control and prevention measures. Massive media coverage of the infection dynamics can generate profound psychological impacts on the public and potentially alter individuals' behavior (De Silva et al., 2009). Whether and how the number of news items from different mass medias is correlated to the infection dynamics during different stages of a disease outbreak remains unclear, and inferring and quantifying this correlation, falls within the scope of this study.

Existing approaches to modeling the media impact on emerging infectious disease prevention and control have focused largely on exploring how media impact depends on the number of infected individuals at different disease stages (exposed, infected,

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hospitalized and dead) (Cui et al., 2008; Collinson and Heffernan, 2014; Li and Cui, 2009; Liu et al., 2007; Sun et al., 2011) and how this dependence affects the final outcome of an outbreak. The dependence, referred to as media function in some of these existing studies, is often incorporated into the incidence rates (or force of infection) (Cui et al., 2008; Li and Cui, 2009; Liu et al., 2007; Sun et al., 2011). The recent work of Collinson and Heffernan (2014) conducted a comparison of different choices of this dependence, and concluded that media functions used in the literature may not best represent the media effect during an epidemic. It was also noted, in the studies (Tchuenche and Bauch, 2012; Xiao et al., 2013, 2015), that this media function depends not only on the number of infected individuals but its change rate, namely, the media induced reduction of incidence rate should be represented by $\exp(-M(I,dI/dt))$ with $M(I,dI/dt)=\max\{0, p_1 I(t)+p_2 dI(t)/dt\}$ (where p_1 and p_2 are non-negative constants). The work of Xiao et al. (2015) shows that due to this media impact, the infection dynamics model becomes a switching system where media impact may switch on (new reports) and off (absence of reports) multiple times, thus contributing to the observed multiple waves of an endemic which have been reported for 2003 SARS outbreaks and in 2009 influenza pandemic.

Despite their success in describing how media impact contributes to multiple waves, delays in the outbreak's peak, and reductions in the outbreak, the aforementioned studies failed to develop functional relationships between the observed media impact and the intensity of mass media coverage in different stages of an outbreak, and the feedback relationship between media intensity (news items, duration, etc.) and the diversity in the type of media (website, TVs, radio, newspaper, etc.) and infection dynamics public information (hospital notifications, mortality, etc.). Developing these relationships and describing how to alter these relationships to achieve optimal disease control outcome (reducing the number of hospital notifications, for example) are objectives of this research. More specifically, we address the following issues: (1) whether the number of news items relevant to the disease is correlated to the disease infection? (2) how strong is this correlation? (3) how the correlation varies during an outbreak? and (4) what outcome can be should we change this correlation?

The rest of this paper is organized as follows. We obtained the number of daily (new) hospital notifications and the accumulated number of hospital notifications of the Shaanxi province (Peoples Republic of China) from the 8th Hospital of Xi'an (the dedicated hospital for the 2009 influenza pandemic in that province), and we obtained the number of daily news items relevant to the 2009 A/H1N1 influenza from eight major websites. We then used the Pearson correlation and cross-correlation analyses to determine the strength of the correlation between these numbers using a variety of statistical techniques (Huang et al., 2011; Haugh, 1976; Koch and Yang, 1986; Sampei and Midori, 2009; Taylor, 1990; William, 2006; Xie et al., 2014; Zhao et al., 2011). Then, we formulated a mathematical model that incorporates a new variable to represent dynamics of media coverage intensity (news items, coverage duration and a response factor of media to the diseases infection) in response to infection dynamics. We also employed the nonlinear least squares estimation to find the best-fit parameter values to the observe data, and calculated the basic reproductive ratio R_0 using the next generation matrix approach (Collinson and Heffernan, 2014; Wang and Zhao, 2008). Next, we numerically simulated the dynamic correlation between the intensity of mass media coverage and disease infection dynamics under different scenarios for media coverage duration and media switch on-off frequencies.

2. Media and infection dynamics: temporal correlation analysis

2.1. Data collection

The laboratory-confirmed cases of pandemic A/H1N1 influenza admitted to the 8th Hospital of Xi'an and the number of new hospital notifications and the accumulated number of hospital notifications for the Shaanxi province from September 3rd to November 16th 2009 are employed in this study. Note that the number of new hospital notifications and the accumulated number of hospital notifications were reported separately every two or three days, and no data were available during the weekends and holidays. To address this irregular reporting, we generated the number of new hospital notifications and the accumulated number of hospital notifications using the cubic spline interpolation method on the surveillance data, and showed in Fig. 1(A and B).

We also obtained the daily news items on the A/H1N1 pandemic from eight major popular websites in the Province: news.cn (xinhua net), sina.com, 163.com, qq.com, people.com, CCTV.com, nhfpc.gov.cn (National Health and Family Planning Commission of the People's Republic of China) and chinacdc.cn (Chinese Center for Disease Control and Prevention) using the key word “A/H1N1” included in the news item title, from September 3rd to November 16th 2009. This is shown in Fig. 1(C and D).

2.2. Data analysis

In what follows, y denotes the number of new hospital notifications. We will also use, for the number of daily news items from each source, x_1 for news.cn, x_2 for sina.com, x_3 for 163.com, x_4 for qq.com, x_5 for people.com, x_6 for CCTV.com, x_7 for nhfpc.gov.cn and x_8 for chinacdc.cn, respectively. We adopt the Pearson correlation (Huang et al., 2011; Taylor, 1990) and the cross-correlation analyses (Huang et al., 2011; Sampei and Midori, 2009; William, 2006; Zhao et al., 2011) methods to explore the relationships between the number of daily news items and the number of new hospital notifications for A/H1N1 in the province during the specified period.

Pearson correlation analysis: Using SPSS software (version 19.0, SPSS Inc.), we conducted the Pearson correlation analysis to determine the association between the number of daily news items and the number of new hospital notifications from September 3rd to November 16th 2009. Some results are summarized in Table 1. We conclude that the number of daily news items from website of 163.com (x_3), qq.com (x_4) and CCTV.com (x_6) is statistically significantly correlated with the number of new hospital notifications over the study period. Among these three popular websites, the number of daily news items of qq.com is most closely correlated with the number of new hospital notifications ($r=0.45$, $p<0.01$), while the correlation for CCTV.com is relatively weak ($r=0.28$, $p<0.05$).

We also report in Table 1 the correlations between each pair of websites. This report shows that some of these websites have statistically significant correlations in terms of reporting the A/H1N1 infection dynamics, some are highly correlated or moderately correlated according to the labeling systems roughly categorized (low or weak correlations ($|\gamma|\le 0.35$), moderate correlations ($0.36\le|\gamma|\le 0.67$) and strong/high correlations ($0.68\le|\gamma|\le 1.0$), Taylor, 1990). In particular, we notice that x_5 is highly correlated to x_1, while x_2, x_3, x_4 and x_8 are moderately correlated to x_1. We also notice the moderate correlation pairs (x_3,x_2), (x_5,x_2), (x_4,x_3), (x_5,x_3), (x_7,x_3), and (x_6,x_4).

Although Pearson correlation analysis can reveal the statistically significant correlation between the number of daily news items and the number of new hospital notifications of A/H1N1, the