Spatio-temporal patterns of influenza A and B across the United States and the influenza vaccine effectiveness in 2011-2018

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Abstract

Objective

We aim to study the spatio-temporal patterns of influenza laboratory confirmations, and the possible correlation with the influenza vaccine effectiveness in the Unites States

Methods

We download the state-level influenza laboratory confirmations and the influenza vaccine effectiveness from 2011 to 2018 in the Unites States. We calculate the ratio of weekly influenza B confirmations over influenza A confirmations. It is generally believed that annual influenza A epidemics are more severe than influenza B epidemics and both epidemics occur in the winter and B tends to be delayed. It is unclear how the ratio of B over A changes in the period from 2011-2018.

Results

We found that the ratio of weekly Influenza B confirmations over Influenza A confirmations peaked in 2015 and it happened that the influenza VE was particularly low in 2015.

Conclusion

The peak in the ratio of Influenza B over Influenza A weekly confirmations in 2015 could be partly due to the low VE in that year in the US. The other reason could be the emergence of a new strain in B/Yamagata lineage in 2014-15.

Introduction

Seasonal influenza has been a widespread threat to public health around the world, causing illness and leading to a great amount of hospitalizations and mortalities. Influenza vaccines are widely used to control the outbreaks and 151 million to 166 million doses are estimated to be available for the 2017-2018 season worldwide. By prognosis from research for the most popular strains of three flu

viruses (i.e., influenza A/H1N1, A/H3N2 and influenza B), the trivalent seasonal flu vaccines will be manufactured to protect against these viruses. However, concerns about the vaccine effectiveness (VE) were raised in recent studies. The VE was estimated as low as 17% against A(H3N2) and 55% against influenza B in Canada (Skowronski et al., 2018), while only 10% against A(H3N2) in Australia Paules et al., 2018). These estimations have raised alarm about VE and made it crucial to study the relationship between influenza outbreaks and VE.

Data Collection and Methods

To investigate the interaction between laboratory-confirmed influenza A and B cases and the VE, weekly outpatient illness and viral surveillance data from January 2011 to April 2018 were downloaded from FluView (http://gis.cdc.gov/grasp/fluview/fluportaldashboard.html, accessed on April 29, 2018), maintained by the U.S. Centers for Disease Control (CDC). These data are on national, regional and state-level, and are from either ILINet (Influenza-like Illness Surveillance Network) or WHO/NREVSS (National Respiratory and Enteric Virus Surveillance System). The data collection process was implemented through *R* package "*cdcfluview*" (https://github.com/hrbrmstr/cdcfluview). Data in Virgin Islands, Rhode Island, New York City, New Jersey and Florida within the studied period are not available. On the other hand, the U.S. seasonal vaccine effectiveness is released online as well (https://www.cdc.gov/flu/professionals/vaccination/effectiveness-studies.htm) and the index of Adjusted Overall VE is used in this study.

The weekly ratio of influenza B over A confirmations in both state-level and country-level is calculated for United States. The influenza vaccine is designed annually to against three strains (Trivalent) or four strains (Quadrivalent). The overall effectiveness is above 40% generally. The statistical analyses and data visualization were implemented in the R programming language (http://www.r-project.org/).

Results

Figure 1 shows the spatio-temporal pattern of the weekly ratio of influenza B over A in 54 states or regions in United States from 2011 to 2018. Annual "peaks and valleys" are observed in most of regions or states. However, spikes particularly stand out in 2015/2016 season, when abnormally high B/A ratio occurred in Ohio, Michigan, Utah, Colorado, Illinois, etc.

The Adjusted Overall VE is presented in figure 2(a) and the weekly confirmations of influenza A and B, and the weekly ratio of B over A are shown in figure 2(b). In 2015, the epidemic onset and peak of influenza A arrived a little bit earlier than other years, followed by a moderate outbreak of influenza B. Unlike other years, the A and B epidemics *staggered* in 2015, which led to a dramatic increase of weekly B/A ratio. Surprisingly, the influenza vaccine attained the lowest VE of the study period in 2015.

Discussion and Conclusions

We report that the weekly ratio of influenza B over A in both state-level and country level showed abnormally high peak in 2015. We also report that the vaccine efficacy is abnormally low in 2015.

We argue that these two events could have some correlation. Statistically speaking, the probability that these two events occur in the same year (out of eight years) is 1 out of 8. This is equivalent to toss two fair dices (assume eight sides for each) and obtain the same side for both. Although this is not statistically significant, the finding novel and interesting and could be of interest to researchers in this field.

This is in line with the finding in He et al. (2015) that the difference in vaccination coverage could possibly cause some large-scale observed patterns. The abnormality in weekly ratio of B over A in 2014/2015 season could be related to the competition between influenza A and B. When the VE is low, the competition for the susceptible pool becomes strong. Therefore, the time delay between influenza A and B epidemics is enlarged. Thus low VE (or low vaccination coverage) favors the "antiphase pattern" between two types or two subtypes. The other reason could be the emergence of a novel strain or clade of influenza B, which was very transmissible and virulent in 2015 (Bedford et al., 2016).

We admit that it could be difficult to evaluate how much the effect of VE contribute to the forming of the spatio-temporal patterns observed in the ratio of B over A, given the complex natural of influenza dynamics. The finding of this "coincidence" is still striking and could provide insights into the prediction and prevention of influenza transmission.

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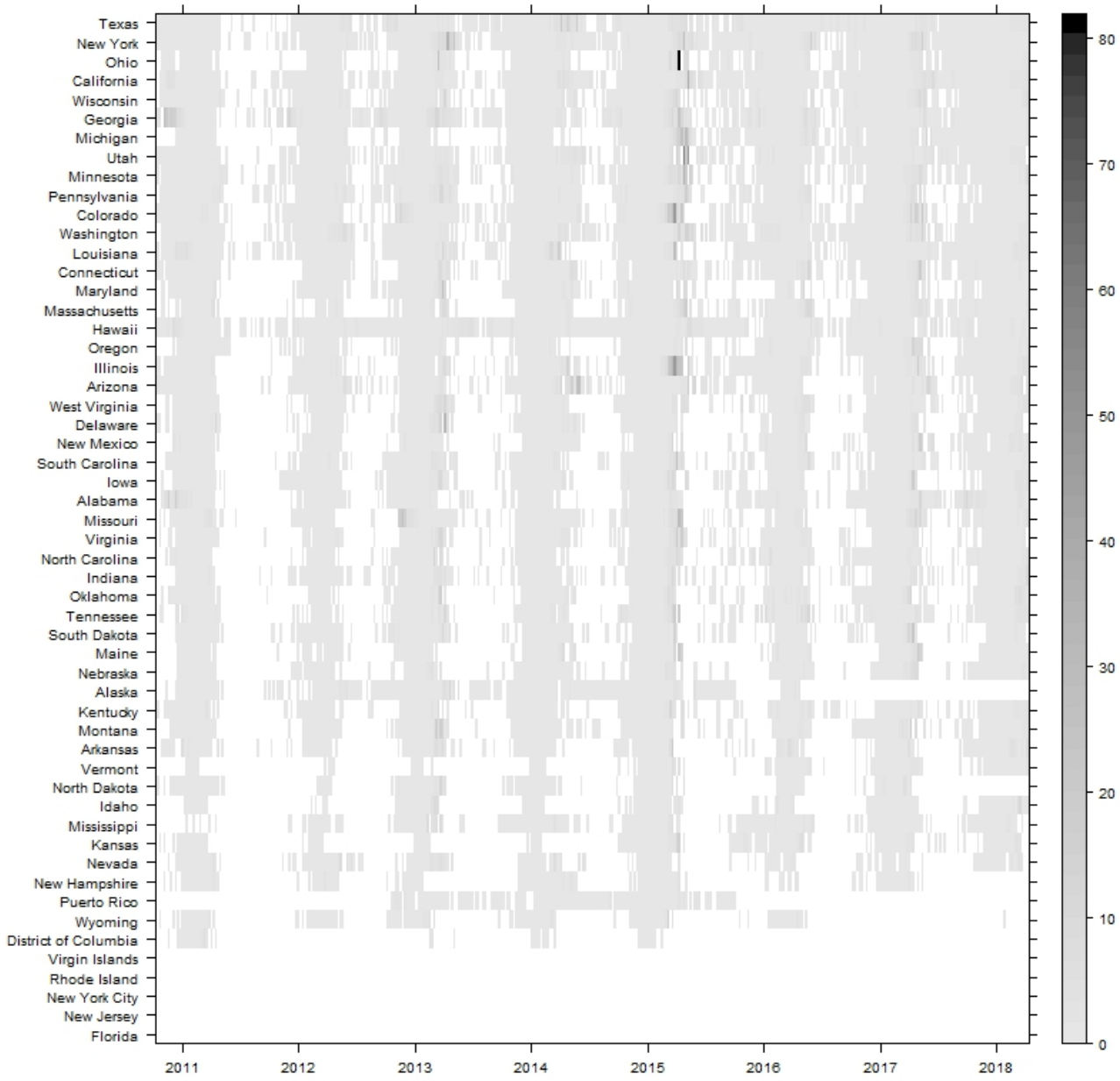

Figure 1. The temporal patterns of weekly confirmation ratio of Influenza B over A in 54 states or regions in United States. The order of the states is according to the total confirmations of Influenza A from top to bottom.

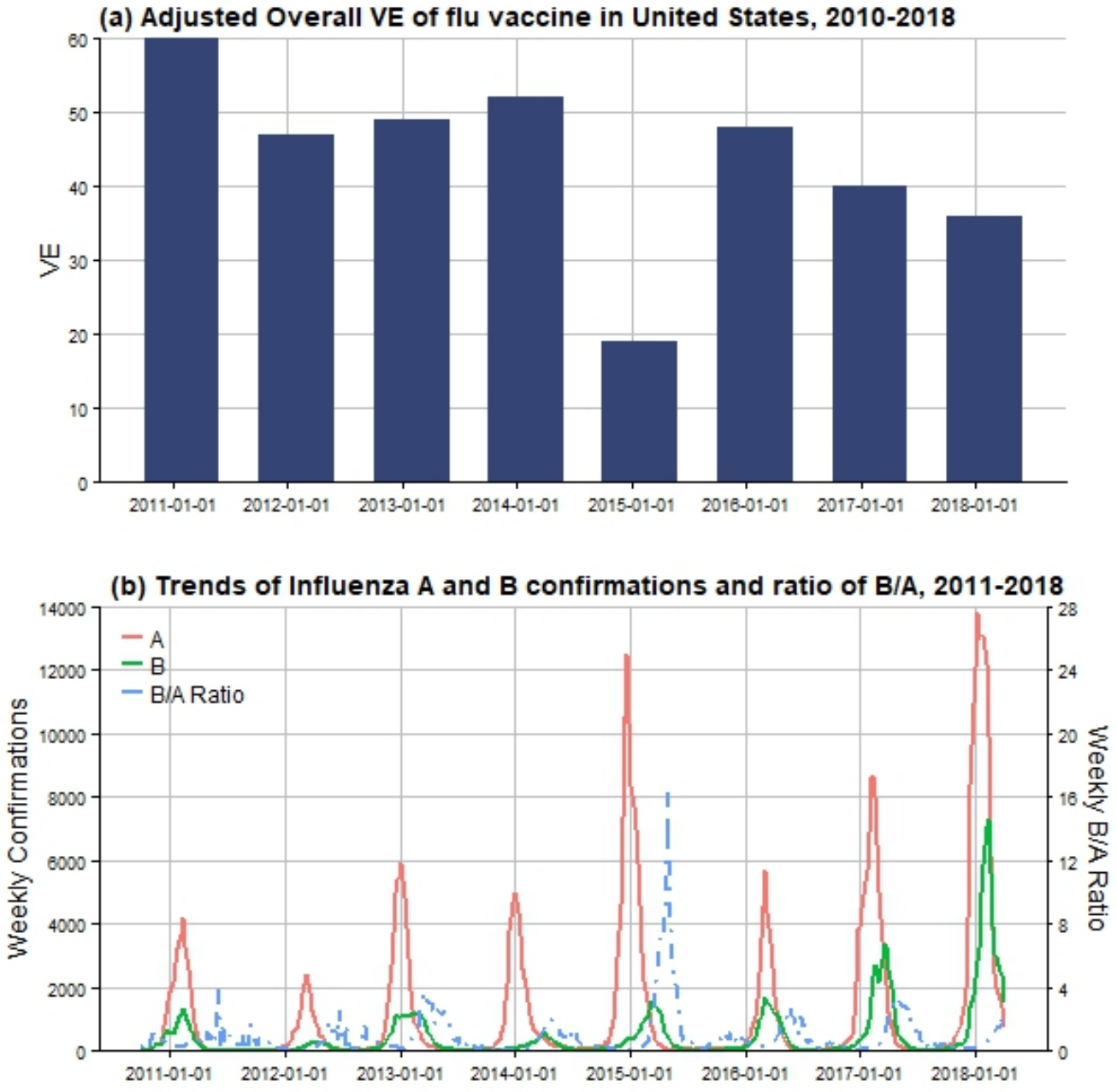

Figure 2. (a) The Adjusted Overall VE of flu vaccine in United States, 2011-2018. (b) Weekly confirmations of Influenza A (red curve) and B (blue dashed curve) and the weekly ratio of influenza B over influenza A confirmations (blue-dotted curve) in United States, 2011-2018. The low VE in 2014-2015 season coincided with the high peak of B/A ratio (blue-dotted curve). The influenza B epidemic was severe in 2017-18 season, but the B/A was not.