Persistence of US measles risk due to vaccine hesitancy and outbreaks abroad

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Results of a measles spatial risk analysis from May, 2019, published in *The Lancet Infectious Diseases*, identified US counties with the highest relative risk of a measles outbreak in 2019.[1] Measles outbreaks have persisted in the USA and globally with over 400 000 cases confirmed in 2019, reversing decades of progress towards measles elimination in many countries.[2,3] In the USA, 1282 cases of measles were reported in 2019 across 31 states and 94 counties, the most since 1992.[4]

In recent years, a growing vaccine hesitancy movement has contributed to decreasing vaccination rates in Europe and the USA.[5] In the USA, the national vaccination rate is 94·7%, representing good coverage on average.[6] However, even if a state has an average vaccination rate that is higher than the threshold for herd immunity, outbreaks can still occur if there exist localised communities with a high proportion of unvaccinated individuals. If such communities are highly connected by travel to regions experiencing large outbreaks, then risk of outbreaks in these communities is increased.

Decreasing vaccination rates, combined with an increase in measles outbreaks abroad and high volumes of international travel, places the USA at increased risk of measles introduction and local outbreaks. In response to these persistent risk factors, we expanded upon our previous work[1] to identify the set of US counties at highest risk of measles outbreaks. The risk to each county was computed with a multiplicative function of four factors: incidence rate of measles at travel origin, international air travel volume from each such origin to a US destination county, measles, mumps, and rubella (MMR) vaccination rates in the county, and county population. This study extends the previous study by using a spatial diffusion model to distribute arriving travellers to US counties near international airports (including counties without an airport), and a comprehensive county-level MMR vaccination rate dataset for 40 states. The final risk measure can be interpreted as the expected relative size of measles outbreak in each county.

Results from the model are illustrated in the figure in appendix 1, which shows the percentage of the population unvaccinated for measles in each US county, the location and relative size of the reported measles outbreaks in 2019, the location of the 20 most visited airports in the USA, and the 30 counties at highest risk of measles outbreaks. A detailed description of the data and methods is provided in appendix 2, and the complete set of results and input data are provided in appendix 3.

See Online for appendix 2

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The results are spatially concordant with the counties that reported measles cases in 2019. Multiple regions in California, New York, Washington, Texas, and Florida are identified as being of highest risk of measles outbreaks, which is concordant with the 2019 outbreaks. Of the 20 highest ranked counties, 17 reported at least one measles case in 2019 and together reported over 700 of the 1276 confirmed cases in the USA. Model results indicate Los Angeles (CA), Seattle (WA), Honolulu (HI), Miami (FL), and Santa Ana (CA) to be the five counties at highest risk, with the Philippines, Samoa, Ukraine, New Zealand, and Israel as countries of highest risk for measles importation to the USA. The four air travel routes posing the highest risk of measles importation ended in Los Angeles and originated in the Philippines, Samoa, New Zealand, and Ukraine. The top 100 US counties and travel routes are listed in appendix 2.

This study has notable limitations. First, the risk model does not fully incorporate the risk of domestic spread within the USA; therefore, it underestimates the risk posed to counties that are highly connected through domestic travel to communities with outbreaks. Second, we use WHO confirmed, as opposed to suspected, cases of measles to estimate country case incidence, which underestimates the risk posed by countries with scarce resources for case confirmation. Third, the model is based on the cumulative number of measles cases reported in each country and total travel volume in 2019. Fourth, in response to the 2019 outbreaks, several countries substantially increased their vaccination rates through immunisation programmes and are therefore less likely to experience a large future outbreak than before these initiatives; thus, the risk posed by these countries is probably overestimated. Fifth, the 2019

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MMR rates that were used for this analysis do not account for recent policy changes and vaccination campaigns in New York, Maine, and Washington; consequently, the risk posed to these states is overestimated. Finally, the effect of COVID-19 on MMR rates in the USA and internationally are not represented. In response to COVID-19, vaccination rates in the USA and globally could drop because of a disruption in regular clinic visits or suspended vaccination programmes. Further, US counties at high risk in this study could represent high risk locations for future COVID-19 outbreaks, if they remain similarly resistant to a COVID-19 vaccine; however, changes in risk perception could increase vaccine uptake.

KK is the founder and CEO of BlueDot, a certified social benefit corporation that builds digital health solutions for infectious diseases. All other authors declare no competing interests.

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