Modelling the importation risk of measles during the Hajj

A major resurgence of measles has occurred in the past 2 years.[1,2] Measles is one of the most contagious diseases, with a reproduction number of around 20. Although a very effective vaccine against measles is available, vaccine coverage is low in an increasing number of countries, including many Muslim countries.[3] The concern is that measles could be introduced via pilgrims to the Hajj and subsequently spread rapidly as a result of the overcrowded situation of the Hajj rituals.[3–5]

The 20 leading countries from where Hajj pilgrims travel are listed in the appendix (p 2), and together with Saudi Arabia, they account for more than 80% of all pilgrims. More than 90% of all pilgrims arrive by airplane (eg, within 24 h after departure from their home country). The majority of pilgrims are born before 1957, and are, therefore, considered measles-immune; however, a non-negligible number of pilgrims are born after 1957, and might hence be susceptible to measles. Using travel volume data, we aimed to estimate the number of measles cases imported into Saudi Arabia for the Hajj 2019 (appendix p 1).

See Online for appendix

Briefly, we obtained data on measles vaccine coverage, measles incidence (reported measles cases divided by population size), and number of pilgrims from each of those 20 countries. On the basis of these data, we calculated the expected number of cases exported from these countries to Saudi Arabia. We assumed that 70% of pilgrims were measles-immune (born before 1957) and calculated the number of susceptible pilgrims based on the vaccine coverage (appendix p 1).

Next, we calculated the expected number of cases arriving still infected in Saudi Arabia assuming that 3% of the pilgrims acquire measles on the day of travel, that an infected individual remains infected for exp(0·1 × time of stay in Saudi Arabia) days, and that the trip to Saudi Arabia lasts around 1 day (appendix p 1).

We then calculated the expected number of susceptible pilgrims arriving in Saudi Arabia by multiplying the number of pilgrims travelling to the Haji by the fraction of measles-susceptible pilgrims (appendix).

Based on these calculations, using data from 2018, we estimated that 110 measles importations will occur during the Hajj. This anticipated number might be even higher given that the measles incidence has increased in 2019 compared with 2018. The six leading countries with the highest number of measles importations into Saudi Arabia will be Yemen, India, Nigeria, Indonesia, Pakistan, and Sudan (appendix p 2).

These 110 imported measles cases could potentially lead to many secondary cases. Fortunately, vaccine coverage is very high (96%) in Saudi Arabia. However, at least 100 000 (5%) of the approximately 2 million pilgrims might be susceptible to measles. The speed of measles transmission among susceptible Hajj pilgrims will depend on the extent of intermixing between pilgrims during the rituals. Given the high reproduction number of 20 in susceptible populations, these 110 imported measles cases could trigger a major outbreak towards the end of the Hajj pilgrimage and result in rapid dissemination globally when pilgrims return to their home countries.

Our modelling suggests that measures should be taken to minimise the risk of measles introduction into Saudi Arabia during the Hajj via incoming pilgrims. First, pilgrim-sending countries should offer measles vaccination before departure to all pilgrims without a measles vaccination record and born after 1957. One might even argue that measles vaccination in countries with suboptimal coverage of the second dose of measles-containing vaccine should become a Hajj entry requirement. Second, Saudi Arabia might want to consider offering vaccination at arrival in Saudi Arabia to all pilgrims from countries with low measles vaccine coverage, although ensuring sufficient vaccine supply and setting up the logistics might not be feasible for this upcoming Hajj. Third, health-care providers during the Hajj need to have a high degree of suspicion regarding measles and be familiar with the clinical management of measles complications. Lastly, public health measures need to be planned a priori, including stockpiling measles vaccines, to ensure a rapid response should a measles outbreak occur.

We declare no competing interests.

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