Evaluating vaccination policies to accelerate measles elimination in China: a meta-population modelling study

Lixin Hao,1 John W Glasser,2 Qiru Su,1 Chao Ma,1 Zhilan Feng,3 Zundong Yin,1 James L Goodson,2 Ning Wen,1 Chunxiang Fan,1 Hong Yang,1 Lance E Rodewald,1,2,4 Zijian Feng1 and Huaqing Wang1*

1National Immunization Program, Chinese Center for Disease Control and Prevention, Beijing, PRC, 2National Center for Immunization and Respiratory Diseases, Centers for Disease Control and Prevention, Atlanta, GA, USA, 3Department of Mathematics, Purdue University, West Lafayette, IN, USA and 4Epidemiology Team, Office of the World Health Organization Representative in China, Beijing, PRC

*Corresponding author. National Immunization Program, Chinese Center for Disease Control and Prevention, 27 Nanwei Road, Xicheng District, Beijing 100050, PRC. E-mail: hqwang@vip.sina.com

Abstract

Background: Measles is among the most highly infectious human diseases. By virtue of increasingly effective childhood vaccination, together with targeted supplemental immunization activities (SIAs), health authorities in the People’s Republic of China have reduced measles’ reproduction number from about 18 to 2.3. Despite substantial residual susceptibility among young adults, more in some locales than others, sustained routine childhood immunization likely would eliminate measles eventually. To support global eradication efforts, as well as expedite morbidity and mortality reductions in China, we evaluated alternative SIAs via mechanistic mathematical modelling.

Methods: Our model Chinese population is stratified by immune status (susceptible to measles infection; infected, but not yet infectious; infectious; and recovered or immunized), age (0, 1–4, 5–9, …, 65+ years) and location (31 provinces). Contacts between sub-populations are either empirical or a mixture of preferential and proportionate with respect to age and decline exponentially with distance between locations at age-dependent rates. We estimated initial conditions and most parameters from recent cross-sectional serological surveys, disease surveillance and demographic observations. Then we calculated the reproduction numbers and gradient of the effective number with respect to age and location-specific immunization rates. We corroborated these analytical results by simulating adolescent and young adult SIAs using a version of our model in which the age-specific contact rates vary seasonally.

Results: Whereas the gradient indicates that vaccinating young adults generally is the optimal strategy, simulations indicate that a catch-up campaign among susceptible adolescent schoolchildren would accelerate elimination, with timing dependent on uptake.