

Benefit of vaccination in protecting the departments of Grand'Anse, Ouest and Sud against a potential second epidemic wave of cholera

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This work is presented as a collaboration between Epicentre Paris-Genève and the Laboratory of Ecohydrology of the Ecole Polytechnique Fédérale de Lausanne¹.

This analysis uses cholera and rainfall data available up to epi week 43; model predictions presented herein are subject to change when further updated as additional data become available.

Introduction

In a previous report [1], we presented model projections based on data available up to epi-week 43 (ending Oct-29). These projections suggested that, due to anticipated heavy rainfalls at the end of November, a second peak of cholera might be observed in early December in the departments of Grand'Anse and Sud, with potential propagation to other departments.

These projections supported the strategy of the MSPP² OCV³ campaign to vaccinate 800,000 people in these two departments, which were also the areas most affected by damage from Hurricane Mathew in early October.

Eventually, the vaccine campaign took place from 11 to 18 November but heavy rainfall was not recorded in late November and no second wave of cholera was observed. In this context, the benefits of the vaccine campaign are difficult to assess since the limited spread is likely the result of non-favourable environmental conditions and the reduction of the susceptible population thanks to the immunization campaign.

Here we show that, had heavy rainfall occurred in late November and early December 2016 (as NOAA was forecasting in late October), the vaccine campaign was effectively designed to considerably reduce the risk of a second epidemic wave in Grand'Anse and Sud, with more limited effects in Ouest department.

¹EPFL (Enrico Bertuzzo, Flavio Finger, Damiano Pasetto) designed the model and performed the analysis. Epicentre (Anton Camacho, Sandra Cohuet, Francesco Grandesso, Francisco Luquero, Emily Lynch) produced the report and recommendations. Both teams interpreted model results. Epicentre team is funded by MSF.

²Ministère de la Santé Publique et de la Population

³Oral Cholera Vaccine

Objectives of the analysis

To assess the impact of the OCV vaccine campaign in mitigating the risk of a second epidemic wave of cholera, given anticipated heavy rainfall, in the departments of Grand'Anse, Ouest and Sud.

Results

The model was calibrated to cholera [2] and rainfall [3] data available up to epi-week 43. The model was then projected through the end of January 2017 using a rainfall forecast obtained from the National Oceanic and Atmospheric Administration [4]. This projection was done with and without accounting for the vaccine campaign that took place from 11 to 18 November.

The figure below shows that without vaccination (in green) a second epidemic peak, potentially larger than the one following Hurricane Matthew, could have been expected in early December, following rainfall in late November. However, the same model, reforecast to account for the vaccine campaign (in red) shows a more reassuring scenario, with both the median and 95% credible interval forecasting the second epidemic wave as smaller than the first in Grand'Anse and Sud. By contrast, the vaccine campaign has only a limited effect in reducing the forecasted number of cases in Ouest, suggesting that the dynamics in this department is rather self-sustained.

To quantify the benefit of vaccination, we computed the probability that the second epidemic wave would be “bigger” than the first one according to two criteria:

- 1) Maximum number of cases at the peak.
- 2) Total number of cases during the epidemic wave.

The results are presented in the table below and show that the risk of having a second peak higher than the first one decreases from ~30% to ~3% in Grand'Anse and from ~50% to ~3% in Sud. In comparison, the risk of a higher second peak in Ouest was less likely (16.5%) but is only slightly reduced (14.5%) by the vaccine campaign, due to indirect effects (e.g. less introduction of cholera from Grand'Anse and Sud to Ouest). The benefits are similar when considering the total number of cases.

Our analysis shows that given the data available before the OCV campaign, the targeted departments were the ones at highest risk of having a second peak of cholera early December. By contrast, a second epidemic peak was much less likely in other departments, like Ouest. Furthermore, our results suggest that, for at least the short term, the OCV campaign targeted enough people in Grand'Anse and Sud to prevent a resurgence of a cholera peak in case of heavy rainfalls. However, the OCV campaign would have had a limited effect on reducing that risk in other departments, mainly because, once introduced, cholera transmission is self-sustained.

Operational recommendation based on model results

- Although model results suggest the number of cholera cases in Grand'Anse and Sud should keep declining after OCV campaign, there is still a risk of localised outbreaks for at least 2 reasons:
 - o Coverage might be less than 100% as assumed in the model.
 - o Coverage might be heterogeneous, with pockets of susceptibility remaining within vaccinated areas.
- Several departments in Haiti, including Ouest, Artibonite and North, remain at moderate risk of increased transmission in the following weeks and close monitoring of the cholera trends in these departments is required.

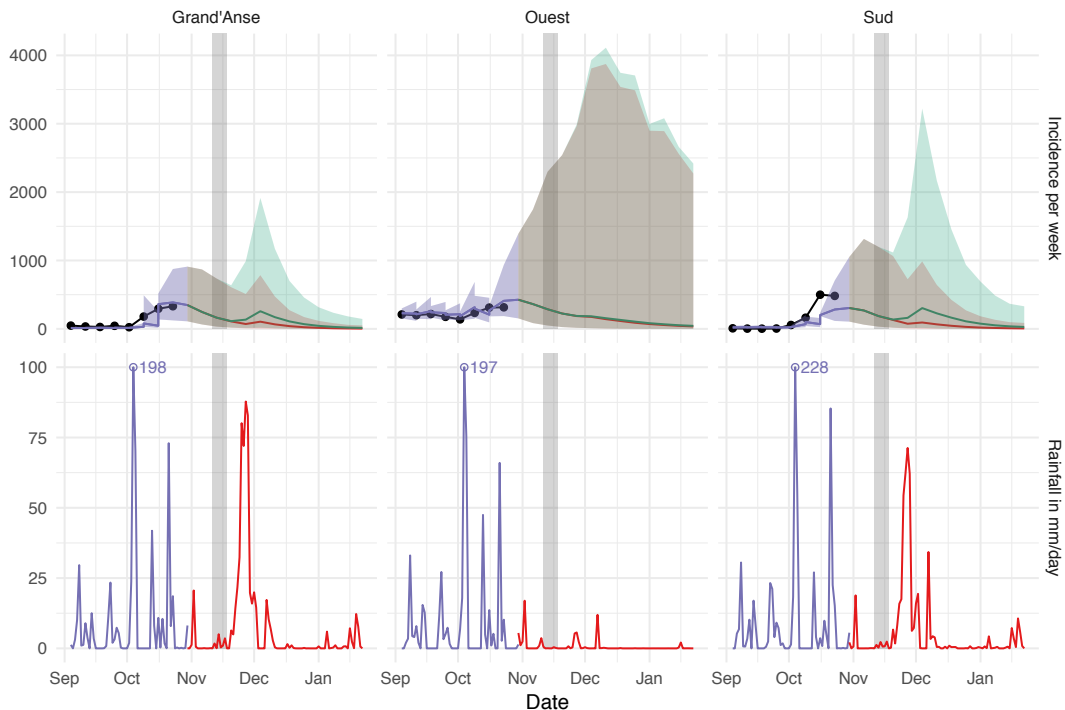


Figure 1 Model projections in Grand'Anse, Ouest and le Sud based on rainfall forecast and with (red) or without (green) accounting for the OCV vaccine campaign that occurred from 11 to 18 November (grey bar). Top panels: black points represent data on which the model is calibrated, solid lines are median fit/forecast of weekly number of cholera cases and shaded envelopes are associated 95% credible intervals. Bottom panels: historical (blue) and forecast (red) rainfall data from NOAA, in mm/day. Note that the y-axis is cut to 100 mm/day and the rainfall peak is annotated.

Table 1 Change in probability of observing a bigger second epidemic wave following heavy rainfall according to two different criteria.

Department	Criteria	Probability 2 nd wave is bigger without vaccination	Probability 2 nd wave is bigger with vaccination	Percentage point difference
Grand'Anse	Peak size	30.9%	3.2%	27.7
	Total cases	18%	0.6%	17.4
Ouest	Peak size	16.5%	14.7%	1.8
	Total cases	14.7%	12.5%	2.2
Sud	Peak size	49.3%	2.7%	46.6
	Total cases	36.5%	0.6%	35.9

Method

We refer to our previous report [1] for a brief description of the model and calibration procedures. Here we briefly explain how the OCV campaign was modelled. We assumed that vaccination would target individuals independently of their cholera infection history (i.e. both susceptible and already immune individuals are eligible). The OCV provides immunity starting with a delay of one week. Vaccinated individuals already immune are assumed to remain completely immune, while vaccinated susceptibles benefit from a leaky immunity with 63% efficacy (thus reducing the susceptibility by 63%). Due to the short time horizon of the forecast, at this stage no assumption is made for the duration of the vaccine-induced immunity. We obtained the list of the communes targeted by the single dose OCV campaign in Grand'Anse and le Sud. As this analysis was completed prior to having actual coverage data, we assumed a maximum coverage rate per commune of 100%, with 800,000 doses distributed. The model assumes a linear ramp-up of vaccine uptake between 11 and 18 of November.

Why model forecasts might not be so accurate?

- The forecast reliability of the model is dependent on the validity and quality of the data used, which is limited to what is currently available in the post-hurricane context. The cholera surveillance network of Haiti has been affected by the hurricane, with many areas remaining inaccessible and many health facilities having sustained significant damage that is affecting their operations. Moreover, cholera cases, particularly at the community level, may be underreported in some areas. The data may therefore not represent the true dynamics of the ongoing epidemic.
- The model disregards several known mechanisms of cholera transmission, for which empirical data is lacking:
 - o Variations in local water and sanitation risk factors related to both chronic and post-hurricane conditions.

- Specific population displacements following the hurricane, which may not be properly accounted for by the human mobility network algorithm used in the model.
- Rainfall forecasts of up to a month in advance might not be reliable.
- The model outputs might be highly sensitive to the prior parameter distribution used to initialize the ensemble. A sensitivity analysis has not been performed yet to prove the robustness of the forecast.
- The vaccine efficacy of the Euvichol oral cholera vaccine has not yet been estimated. For this work, we used recently published [5] estimates of 63% for single dose efficacy of another oral vaccine, Shanchol.
- The duration of immunity provided by the vaccine is not known. Although for the short term this should not affect our forecast (immunity is believed to last at least one year), it may have an impact on the longer term validity of model predictions.
- In this model we assumed a 100%, homogeneous vaccine coverage in the targeted communes. In reality, vaccine coverage is less than 100% and likely to be heterogeneous, which may have an impact on the outcome of vaccination, as pockets of susceptibility can trigger localised outbreaks that are not accounted for by the model.

As more data becomes available, the model will be updated and re-calibrated, thus increasing its forecast reliability.

Ongoing modelling work

- We are currently working on more precise inclusion of the variability of the rainfall forecast from NOAA which, every 6 hours, updates forecasts for 9 months ahead. Because of the chaotic dynamics of weather, these forecasts can differ substantially at different time points. To make more robust predictions, we are working on using an ensemble of rainfall forecasts from NOAA.

Reference

- [1] Prediction of cholera dynamics in Haiti following the passage of Hurricane Matthew. Epicentre & Ecole Polytechnique Fédérale de Lausanne, published 11 November 2016.
- [2] <http://epicentre-msf.shinyapps.io/haiti-2016-cholera/>
- [3] http://iridl.ldeo.columbia.edu/SOURCES/.NASA/.GES-DAAC/.TRMM_L3/.TRMM_3B42RT/.v7/.daily/.precipitation/[8]
- [4] <https://www.ncdc.noaa.gov/data-access/model-data/model-datasets/climate-forecast-system-version2-cfsv2>
- [5] Qadri F, Wierzba TF, Ali M, Chowdhury F, Khan AI, Saha A, et al. Efficacy of a Single-Dose, Inactivated Oral Cholera Vaccine in Bangladesh. *New England Journal of Medicine*. 2016 May 5;374(18):1723–32.