Cholera epidemic in Yemen

Author's reply

Dureab and colleagues[1] concur with our call for urgent measures to enhance cholera preparedness and response in Yemen to stop the outbreak that has persisted for more than 2 years. However, they challenge our finding that the large second epidemic wave was associated with the start of the rainy season from April to May, 2017. They suggest that rainfall is unlikely to be a major risk factor for cholera transmission in Yemen because cholera and rainfall are spatially and temporally variable within the country, and because our analyses used modelled and not measured estimates of precipitation.

We agree that the mechanistic relationship between cholera and and precipitation is non-linear and complex, and varies by context.[2] Therefore, we used a flexible modelling approach that accounted for spatial (ie, district-level) and temporal variability in cholera and precipitation, and allowed for heterogeneous effects of rain across the country while accounting for potential confounders. Across multiple models with different functional relationships between rainfall and cholera, the statistical association remained strong, suggesting a true association between accumulated rainfall and transmission. In view of no working weather stations in Yemen since 2015, the precipitation data are based on remote sensing estimates.[3] However, we expect this to be analogous to non-differential misclassification bias, leading to weakening of the measured association between rainfall and transmission.

While we found a statistical association between accumulated rainfall and transmission, our analyses did not reveal the causal mechanisms behind this association. As discussed in our original manuscript, the war in Yemen has disrupted water and sewage systems and increased fuel prices, making the use of unsafe water and food sources more likely, perhaps even more at the start of the rainy season when surface water is more readily available.[4] In addition, our results do not exclude the possibility that other

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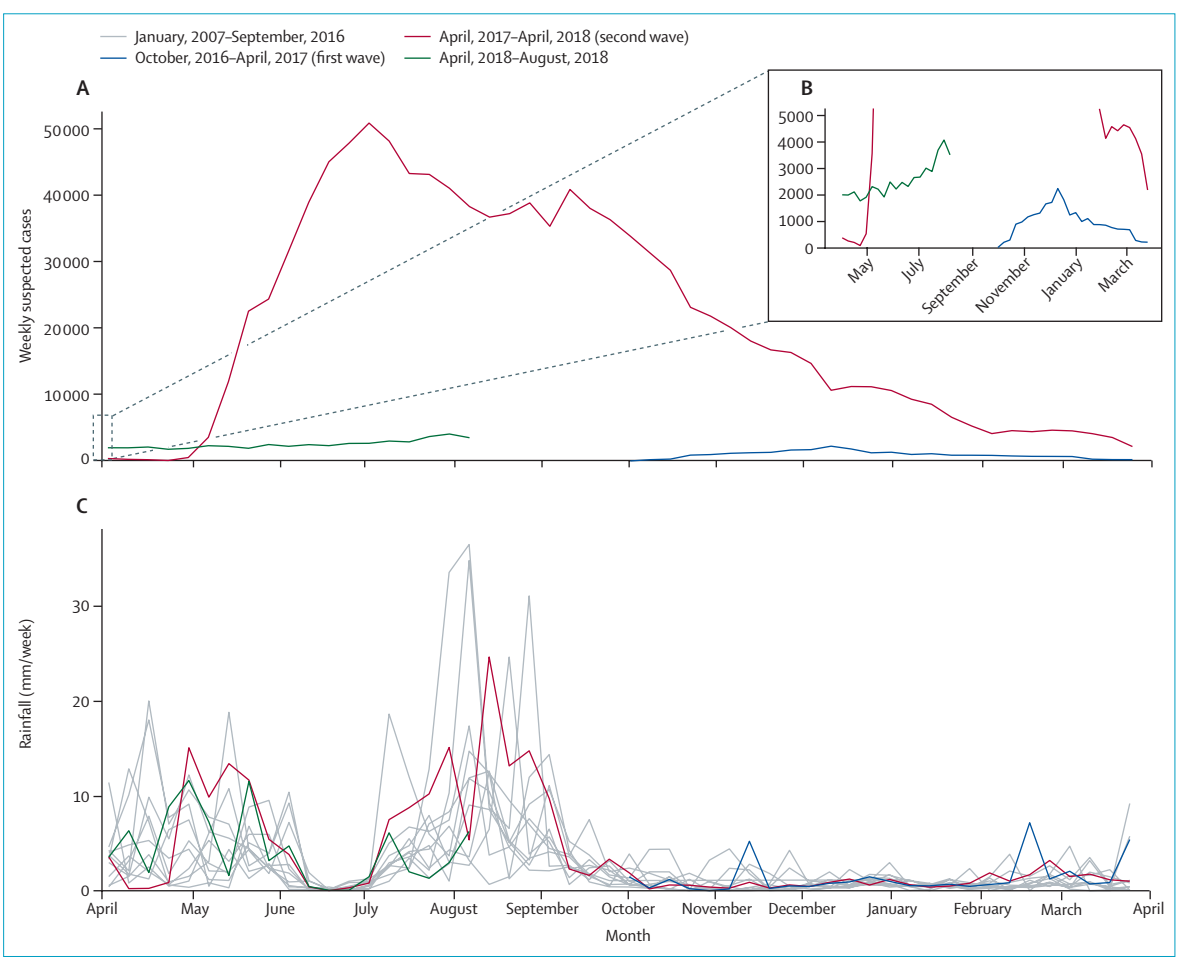

Figure: **Weekly time-series of cholera suspected cases (A, B) and rainfall (C), 2007–18**
The time-axis starts on week 13 (early April). Panel B shows a zoomed view of panel A.

unmeasured factors have affected cholera transmission. Indeed, we found spatial heterogeneity in the relative risk of cholera transmission attributable to rainfall, with coastal arid districts being less at risk during the increasing phase of the second epidemic wave. More work is certainly needed to untangle the mechanistic drivers of cholera transmission across settings and to design tailored interventions, both for epidemic and endemic settings. Nevertheless, our analysis better characterises the spatiotemporal risk of cholera transmission in Yemen, which represents key information for action during the months (from April to August) most favourable for effective spread.

Following the return of rain in April, 2018, a third epidemic wave of cholera started in Yemen (figure). Although reported cases are increasing slower than in the second wave, the 4000 cases reported in week 30 (ending July 29, 2018) represent a peak on the graph twice as high as the first wave. Despite the prevention and control efforts put in place by health authorities, including the cholera vaccine campaigns in the Governorates of Aden, Al-Hudaydah, and Ibb,[5] cholera risk remains high. Efforts to contain the third epidemic wave are compounded by attacks on cholera treatment centres.[5] Therefore we renew our urgent call to ensure health facilities remain safe and accessible and improve cholera risk reduction activities to bring the epidemic to an end.

We declare no competing interests.

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