Supplementary Information: The exacerbation of Ebola outbreaks by conflict in the Democratic Republic of the Congo

Chad R. Wells*, Abhishek Pandey*, Martial L. Ndeffo Mbah, Bernard-A. Gaüzère, Denis Malvy, Burton H. Singer, Alison P. Galvani

This supplement is divided into two sections: (i) a narrative by Bernard Gauzere describing community conflict and violence as observed and experienced during his on-site work in the Democratic Republic of the Congo (DRC) with Medecins Sans Frontieres and (ii) data and modeling details. The model simulation and analysis, conducted in MATLAB, for the Ebola outbreak in North Kivu and Ituri is publicly available (1)**.**

Table of contents

Part 1—Description of conflict and violence **2**
Background information for North Kivu and Ituri provinces in the DRC *2*
Narrative on conflict and violence *3*

Part 2—Data and Modeling **11**
Model ***11***
Disease dynamics *11*
The impact of conflict events on disease control measures *13*
System of equations *14*
Selection of saturation function *15*
Extension of model *16*
Data ***16***
Weekly incidence data *16*
Conflict data *16*
Model fitting ***17***
Model parameterization *17*
Priors *19*
Likelihood *20*
Estimates of the effectiveness of disease control *21*
References ***27***

Part 1—Description of conflict and violence

Background information for North Kivu and Ituri provinces in the DRC

On August 1, 2018, the public health authorities of the Democratic Republic of the Congo (DRC) declared an Ebola outbreak in the conflict-ridden province of North Kivu (2). Despite the efforts of government and foregin aid organizations, the epidemic has persisted to become the country's biggest and deadliest outbreak (3, 4). As of June 11, 2019, there have been 2084 cases and 1405 deaths(5). The 2018 North Kivu-Ituri Ebola outbreak was declared just eight days after the end of one in Equateur DRC.

The Equateur outbreak was announced over within two and a half months from its declaration due to adequate contact tracing and the deployment of the experimental vaccine—recombinant vesicular stomatitis virus–Zaire Ebola virus (rVSV-ZEBOV) vaccine(6). Deploying vaccination not only played an important role in curtailing the epidemic expeditiously (7), it also increased public awareness of the disease and likely improved practice of Ebola safety precautions (8). In North Kivu and Ituri, public health officials are confident that the vaccine is contributing towards a reduction in incidence (9, 10). Unlike the Equateur province, provinces of North Kivu and Ituri have been one of the neglected regions, under the control of militias, and characterized by a large number of internally displaced people. Armed clashes and mistrust and rumors among residents continue to raise safety concerns among locals and make the control response challenging (10–15).

Armed conflicts and civil unrest contribute to the spread of infectious disease through disruption of disease control programs and breakdown of the healthcare system (16, 17). For example, in Central Republic of Africa, armed conflict restricted patient access to antiretroviral therapy and caused the temporary evacuation of healthcare workers (18), or in the case of cholera, where sanitation systems were destroyed in Yemen (19). In Uganda, the introduction of Ebola was possibly caused by the movement of

Ugandan troops or by Sudanese rebels during 2001 (16). On the other hand, many years of civil war left Sierra Leone's health care system depleted, inadequately equipped and understaffed, which ultimately put the healthcare workers at higher risk of infection, exacerbated transmission and made the 2014 epidemic uncontainable (16, 20).

The violence in Eastern DRC is centralized around politics, armed groups, land ownership, and economics (21, 22). A prime example is the mining villages that undergo a rapid transformation from a rural to an urban setting, becoming densely populated with a wide diversity in ethnicity, and the destabilization of infrastructure due to the presence of the military, political actors, and armed groups (22). Armed groups often exploit the political or economic situation in an urban center (21), making it a prime environment for them to reside (22). There are over 70 armed groups in the Eastern DRC, and they have become more concentrated in some areas due to a loss of territory (21). The province of North Kivu has been an epicenter of armed conflict in the eastern part of DRC for several years (11, 23, 24). For example, a Ugandan armed group called the Allied Democratic Forces (ADF) is one of the most active groups in the Beni Territory, while the Maï-Maï Kilalo is the largest identified armed group in the outbreak area (25). In mid-April 2019, the Islamic State militant group asserted its first attack in Kamango, a village near Beni in the DRC (26). The presence of this group in a volatile and impoverished region is concerning based on their destructive behavior in the Middle East.

Narrative on conflict and violence

Bernard Gaüzère

Centre René Labusquière, Université de Bordeaux, Institut de Médecine Tropicale. Pathologies infectieuses, Vaccinologie, 146 rue Léo Saignat - Case 58. 33076 Bordeaux (France)

The information reported herein is based on observations and experiences when I was deployed as a senior Ebola MD with Médecins Sans Frontières (MSF) in Katwa (DRC). I arrived on the 18th of January,

2019 and left on the 26th of February, 2019 after the Ebola treatment center (ETC) in Katwa was destroyed. My background is in intensive care and tropical medicine. Prior to deployment to Katwa, I was in charge of an ETC in Guinea with the French Red Cross during the 2014-2016 West African Ebola outbreak and in 2018 was in charge of two Lassa fever programs in Southern Nigeria.

There were two ETCs in the area of Butembo and Katwa. The ETC located in Butembo was the largest with 85 beds and run by MSF Swiss, and its operation started in September of 2018. The ETC in Katwa, that I ran, began operating the first of January 2019 and was managed by MSF France and MSF Belgium. This ETC was approximately 100 m x 100 m and had a maximum capacity of 70 patients.

The Katwa ETC was located near a village close to a forested area. These two ETCs were approximately six kilometers apart, roughly 20 minutes drive away from each other. The ETC in Katwa opened because there were many cases coming in from the Katwa region. In February, the Alliance for International Medical Action (ALIMA) opened an Ebola transit center located in the Katwa regional reference hospital, not far from the ETC in Katwa, and had approximately 20 beds. The role of a transit center is to refer Ebola positive cases to the ETC, to reduce the number of suspected cases in an ETC.

The area of these ETCs was not safe in the sense that the whole area has been troubled with "civil war" for many years (about 20 different armed groups of various origins), particularly for the last three years. The ETC was not only treating Ebola cases but was also taking care of a lot of other conditions for free. For example, some cases of malaria or typhoid, respiratory tract infection, fever of unknown origin, miscarriages, sinusitis, chronic respiratory failure, gastro-enteritis, and etc. were treated for the disease and released as they were initially referred to the ETC for symptoms compatible with Ebola. Most of the cases sent to the ETC were not necessarily Ebola cases, but the patients exhibited fever like symptoms.

Health care in the DRC is not free, as the patient has to pay for everything from the gauze used to the doctor, and the level of care is not what it should be. Anyone sick could come and get free treatment at an ETC, for whatever disease they had. If an ETC patient with two negative Ebola PCR 48 hours after symptoms was referred to the local hospital for non-Ebola related treatment, MSF would cover all the patients expenses in the hospital after their referral.

There were two major signs that indicated a pending attack on the ETC in Katwa. The first sign was a change in the public behavior towards the MSF team. Every morning, some of the MSF team would take a 30 minute walk from their hotel to the ETC. Most of the time we had school children playing with us and the people waving at us. This behavior changed on February 17,when the residents began shouting "Ebola, Ebola, Ebola" at the MSF team, as we were identified as Ebola workers. There was no physical hostility at this point towards the MSF team.

The second, more crucial, sign that indicated residents were aware of an imminent attack was the tremendous decrease in suspected cases sent to their ETC. On average, the health authorities would send the ETC 35 to 40 suspected Ebola cases a day. The day before the attack there was only one suspected case sent. I was on call the day of the attack and the ETC only received two suspected cases. In the days preceding the attack, there were many rumors circulating, suggesting that the ETC was used for experiments on patients, organ trafficking, or that the Ebola virus does not exist. There were no real threats or anything malicious towards the MSF team.

On Sunday night, the 24th of February 2019, there were 30 health workers and only 10 patients at the ETC during an attack. Four out of the 10 patients were confirmed Ebola cases. At 10:40 PM the ETC was surrounded by dozens of people who started throwing stones for 20 minutes. Immediately after, they started a fire around the ETC and tried to set fire to the chlorine stock. Fortunately, they were

unsuccessful, as the whole structure would have been destroyed due to the explosion. During the attack there was one casualty, a relative of a patient who was staying in the camp near the ETC. The camp was set up to host patient's family members. This individual drowned in the river while attempting to escape. Following the attack, all of the confirmed Ebola cases were transferred to the Butembo ETC. Identification of the assailants was impossible because it was too dark. However, the attackers were from the area as they were speaking the local language.

With the Katwa ETC out of commission, the Ebola transit center located nearby was transformed into an ETC. Five weeks after the attack, the ETC in Katwa was up and running again, but this time under the management of the DRC Ministry of Public Health with funding from the WHO/UNICEF and the international community. After this attack, security was greatly reinforced at the Katwa ETC with the presence of several military guards.

On Wednesday the 27th of February 2019 at 6:00 pm the ETC in Butembo—monitored by the military to ensure safety—was attacked. This attack was more vicious and elaborate than the one in Katwa, as the attackers knew what they were looking for. The attack occurred during shift change of the afternoon and evening team.The attackers tried to force entrance with two cars, and they shot at people. They also had relevant information about the ETC, as they did not enter the "red zone" where confirmed cases reside, but went straight for the power plant and shot at the power supply. The loss of power caused the oxygen supply to go down. As a result of a lack of oxygen, two patients died. One particular person was being targeted during the attack, an intensive care unit specialist from Mexico who was in charge of the confirmed cases. The rest of the assailants kept demanding the doctor, as they went to look for him. It seems that a policeman was also killed during the attack.

On Saturday the 9th of March 2019, the ETC in Butembo was attacked again despite being heavily protected by the police and army, and was now operating under the management of the Ministry of Public

Health. During the attack, a policeman was killed and several staff were wounded. After the second attack, the ETC became almost a military camp, making it difficult to destroy. On the 14th of March 2019, two other ETCs were attacked—one in Mamdowa, located near Lubereo and another in Biena.

In the months leading up to the attacks in Butembo and Katwa, two hours away in Beni, 40 to 50 health care centers had been attacked and destroyed. As the situation in Beni improved, the violence seemed to migrate to the Butembo and Katwa area.There are many potential reasons why these attacks occurred and hostility increased in the area. One reason is that the eastern part of the DRC was denied the right to vote in presidential election in December because it is a well-known place of the opposition and they represent two to three million voters. The residents did not appreciate this particular action. In addition, when the Ebola operations started, the MSF teams were associated with the Ministry of Health, meaning the government, by some of the residents in the area. In the eyes of the residents, the MSF teams were linked to denial of their right to vote.

Another explanation for the attacks and the increase in hostility is related to confusion surrounding the response to the epidemic. For example, some of the rumors circulating concerned foreigners experimenting on locals, taking organs, or filling the bodies with concrete or cement. Belief in these rumors is quite normal during an Ebola outbreak. The attacks were really Ebola related and well-planned military type attacks that were meant to kill, and not just grieving families taking revenge.

A more subtle point was the Ministry of Public Health not really trusting the safety and security of the ETCs, as the costly equipment for the polymerase chain reaction (PCR) was not within the premises of the ETC. The Ministry of Public Health did not want this equipment to be destroyed if there was an attack. The Ministry of Public Health was right to do this, as these two labs (one in Butembo general hospital, one in Katwa Reference regional hospital) were not attacked during the attacks of the ETCs and were able to continue working. The operation of the PCR equipment is crucial to the diagnosis of Ebola.

There was little massive population movement to other places as a result of these hostilities. People in Africa travel a lot in general, for weddings, family gatherings, or funerals. For much of the outbreak, the epidemic has been well contained to the affected areas. There have only been a few rare instances where cases have been reported outside the affected health zones. Two positive cases from DRC were diagnosed in the neighbouring country of Uganda without triggering an outbreak. There was also one event of a pastor who was positive for Ebola reaching Goma. He later died on the way back to Butembo. It was felt that if the epidemic ever reached Goma, that would be extremely concerning because Goma is heavily populated with approximately half-million people and thousands of Congolese people cross the adjacent Rwanda border every day for work. At the present time, August 2019, it is in Goma.

The impact of these attacks on continuing treatment was relatively minimal. The Butembo ETC was only partially destroyed and was back in action immediately and the ALIMA Ebola transit center was quickly converted into an ETC, pending the re-opening of the ETC in Katwa. When the Ministry of Public Health took over the ETCs, the primary worry was the lack of care from the local doctors and nurses, due to their lack of training in interpreting the test results,.

Vaccination centers do not seem to be a target for attacks. However, the hostility in some regions prevented vaccination teams from reaching certain populations. For example, the heavily populated suburb Muchanga in Katwa was not accessible to response teams, as they were constantly denied access despite most Ebola positive cases and community death from Ebola being among those living in that suburb. A group of Maï-Maï were opposing any foreigners or any member of the response team to enter the area. Also, there was an incident of a Ministry of Public Health response team being attacked right in the middle of Butembo. The hostility towards the Ministry of Public Health was partly due to non-locals being recruited for the response teams. The Ministry of Public Health was recruiting relatives and people outside the area. The use of foreigners, whether Westerners or people from Kinshasa or Beni, made the

locals upset as the government was not using their people. This use of foreigners increased the hostility towards these response teams, as published in posters in town (Figure S1).

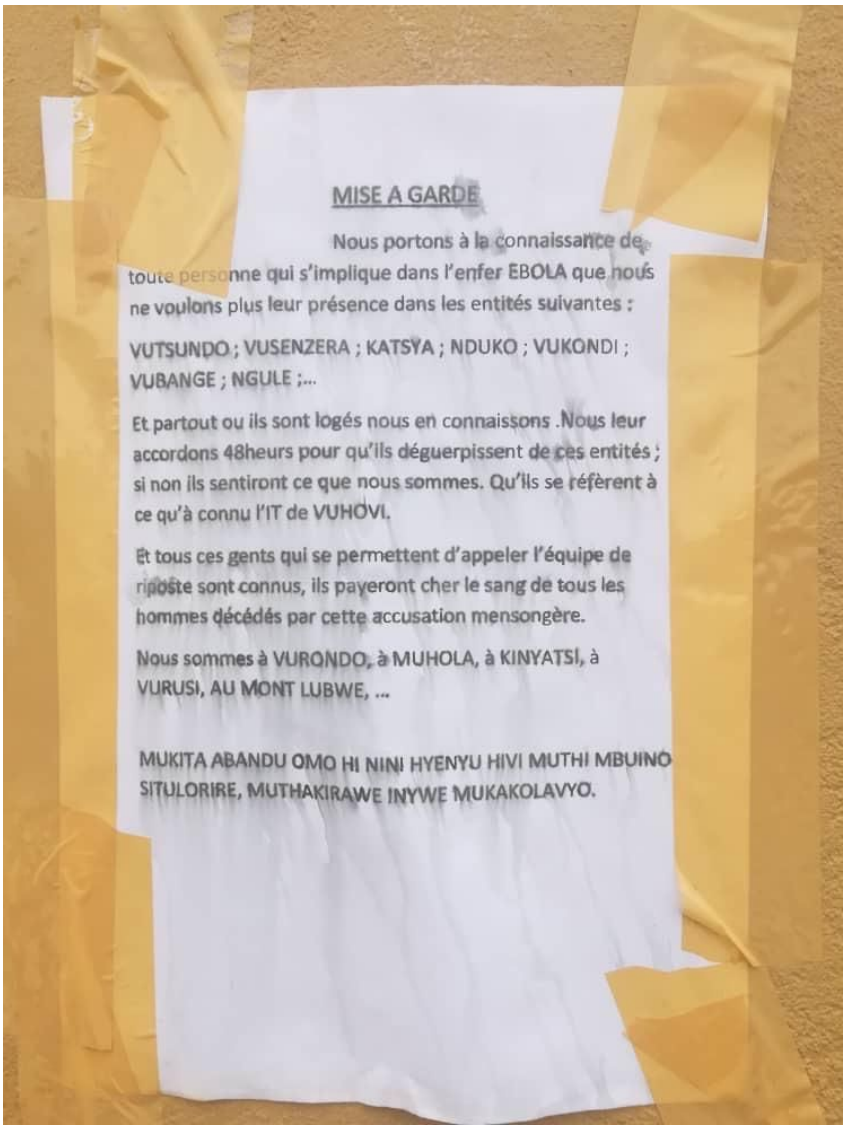

Figure S1: A poster distributed after the attack on the Katwa ETC on February 24, 2019. See translation in the text.

Warning

We inform all involved persons in the EBOLA infierno that we don't want them anymore in the following places: VUTSUNDO; VUSENZERA; KATSYA; NDUKO; VUKONDI; VUBANGE; NGULE; …

And everywhere where they are housed, we know. We give them 48 hours to decamp, or else they will come to know who we are. They just have to remember what happened to VUHOVI center. (ed: Local name of Katwa ETC)

And to all people who allow themselves to call for the response team, they will dearly pay for the blood of all deceased men because of these untruthful indictment.

We are at VURONDO, MUHOLA, KINYASTI, VURUSI, MONT LUBWE, …

Butembo and Katwa are neighboring health zones, but Katwa has approximately three times as many cases as Butembo. One clear explanation for this difference is the spatial and social demography of the two areas. There is a road that runs through the city of Butembo. To the left of this road is Butembo, which is quiet rich and Catholic and belongs to 11 to 12 wealthy families. To the right is Katwa, which is more of a rural area, primarily Protestant, much poorer than the residents of Butembo, and likely less educated. Most of the cases were coming from the suburb of Muchanga, a place where no preventive action was ever possible. Other cases in Katwa were coming from the eastern part, coming as far as 40 kilometers away. Also, at the beginning of January of 2019 a member of parliament, who is a Butembo representative, gathered the population in town and said that Ebola does not exist. He went on to say that Ebola is a pure invention of the West (Kinshasa) and then shook the hand of a lady who—he said—had Ebola to prove he would not die. This action likely encouraged people not to seek early treatment to an ETC. Also, some patients being forced by the police to the ETC, where more than half of them end up dying, further fostered the hostility within the local population and their beliefs in rumors.

Superimposed on top of all this local hostility, there are groups that are funded from Uganda and Rwanda that are looking for the mines located in DRC. There are many private interests in the area, who are not really keen on having people from Kinshasa or Westerners having a look into their business. In that respect, Ebola is a problem because it brings a lot of attention to the area, particularly to local arrangements and businesses. For the past 25 years, Rwanda has been very influential in that area of the DRC as it considers it an economic influence and cultural zone. The main objective of these groups is to keep people from Kinshasa away from the area.

To reduce hostility towards the response, the MSF employs local people and does not over-pay them so that there is not a feeling of injustice. However, the MSF were only allocated some places in Katwa and Butembo and not allowed to go to other places because the Ministry of Public Health wanted to work in these areas. This process is not standard for the MSF, as they tend to cover an entire area. However, the Ministry of Health did not want to conduct the response this way. The minimalist effect of this approach is the misunderstanding of the local population, where the maximum effect is the well-organized military kind of attacks just trying to isolate this part of the DRC from Kinshasa. If you want to be successful here, the most important thing, before anything else, is to talk to the people and have the local community talk to each other.

Part 2—Data and Modeling

Model

Disease dynamics

We developed a modified SEIR (susceptible-latent-infectious-recovered) transmission model. Given that the cumulative incidence of an Ebola outbreak generally represents an extremely small fraction of the population, we set the susceptible population (*S*) to be constant over the course of the outbreak (27–30). The latent and infectious period in a standard SEIR type transmission model follows an exponential

distribution (*i.e.*, the period is considered a single stage). However, the transition between the stages of infection does not always follow this exponential distribution. The Erlang distribution (gamma distributions with integer shape parameter) allows for a non-exponential distribution (*i.e.*, periods divided up into more than one stage) to be easily incorporated into a system of ordinary differential equations. Therefore, we used Erlang distributions for the latent (E) and infectious (I) periods (31) by dividing the latent and infectious compartments into n_E and n_I stages, respectively (Eqs S1-S6). The use of the Erlang distribution allows the model to be generalizable to other diseases and to be adjusted to any future changes in the shape of the distribution.

Susceptible individuals become latently infected at rate,

$$\beta(1-\varepsilon)\Omega(t)\sum_{i=1}^{n_I} I_i(t),$$

where $I_i(t)$ is the prevalence for stage i of infection, β is the rate of infection, ε is the population level effectiveness of vaccination, and $\Omega(t)$ is a saturation function. We assume that only at-risk contacts are targeted for vaccination and the population level effectiveness ε implicitly accounts for the vaccine efficacy as well as the coverage and efficiency of the vaccination campaigns. The impact of vaccination is incorporated in the model by reducing the force of infection by $(1-\varepsilon)$. For this function, we used

$$\Omega(t) = \frac{1}{1+(KC_I(t))^n}, \tag{S1}$$

where $C_I(t)$ is the cumulative incidence, K is the saturation constant, and n is the Hill coefficient. Once infected, an individual spends an average of $1/\alpha$ days in the latent period before coming infectious.

We assume that the individual becomes symptomatic once infectious, where the average time from symptom onset to isolation is $1/\gamma$ days. The time to isolation in the model accounts for the duration of infectiousness in the community for Ebola cases, which includes individuals who are not isolated and either recover or die. Thus, once isolated the individual is removed (R) from the general population.

The impact of conflict events on disease control measures

Based on the descriptive narrative of the events that unfolded during the Ebola treatment center attack in Katwa, the public health response is impacted before and after the event occurs. We assume that the effect of the event peaks on the day it occurs. Thus, the impact of a single attack at time t_i is

$$A(t, t_i, \omega) = \begin{cases} \max\{0, (t - t_i)/d + 1\}, & t \leq t_i \\ \exp\{-\omega(t - t_i)\}, & t > t_i \end{cases}, \quad \text{(S2)}$$

where t_i is the time of attack i, d is the number of days before the critical event that disease control is inhibited, and ω is the rate disease control returns to baseline after an attack.

Based on the ethnographic description of the Ebola treatment center attacks in Butembo and Katwa, there is heterogeneity in the magnitude of impact these events have on the public health response depending on their location. For example, the attack on the Butembo ETC on February 26, 2019 was much more elaborate than the attack on the Katwa ETC on February 24, 2019 (SI Narrative). Similarly, the magnitude of impact also varies depending on the type of the conflict event. For example, the ADF attack in Beni in September resulted in the declaration of a five day ville morte, which resulted in only 20% of contacts to be followed during that time. Whereas attacks described in the ethnographic narrative had relatively minimal impact on continuing treatment. The location dependent weights differ for the time to isolation and the effectiveness of vaccination. Thus, the maximum impact of a critical event is dependent on its location and type and is incorporated in the model using weights w_Z and m_B where Z represents the health zone where the event occurred, B represents the type of the event. We compounded the effects

of the critical events on disease control where there are multiple events. Thus, the impact of these critical events reducing disease control is

$$V(t,\omega) = 1 - \left(\prod_i (1 - w_{Z_i} m_{B_i} A(t, t_i, \omega)) \right), \tag{S3}$$

where i is the critical event.

The effect of the time from symptom onset to isolation and the population level effectiveness of vaccination on the transmission dynamics differ. Thus, conflict events have distinct impact on the time to isolation, denoted ω_I and the effectiveness of vaccination, denoted ω_V. We express the time from symptom onset to isolation in the presence of conflict as

$$\frac{1}{\gamma} + gV(t, \omega_I), \tag{S4}$$

where g is the maximum number of days a conflict event can extend the time to isolation. Similarly, the effectiveness of vaccination is expressed as

$$\varepsilon(1 - V(t, \omega_V)). \tag{S5}$$

System of equations

$$\frac{\mathrm{d}E_1(t)}{\mathrm{d}t} = \beta(1-\varepsilon(1-V(t,\omega_V)))\Omega(t)\sum_{i=1}^{n_I} I_i(t) - \alpha n_E E_1(t) \tag{S6}$$

$$\frac{\mathrm{d}E_j(t)}{\mathrm{d}t} = \alpha n_E E_{j-1}(t) - \alpha n_E E_j(t) \tag{S7}$$

$$\frac{\mathrm{d}I_1(t)}{\mathrm{d}t} = \alpha n_E E_{n_E}(t) - \frac{1}{\frac{1}{\gamma}+gV(t,\omega_I)} n_I I_1(t) \tag{S8}$$

$$\frac{\mathrm{d}I_j(t)}{\mathrm{d}t} = \frac{1}{\frac{1}{\gamma}+gV(t,\omega_I)} n_I I_{j-1}(t) - \frac{1}{\frac{1}{\gamma}+gV(t,\omega_I)} n_I I_j(t) \tag{S9}$$

$$\frac{\mathrm{d}C_I(t)}{\mathrm{d}t} = \alpha n_E E_{n_E}(t) \tag{S10}$$

Accounting for the effects of conflict, the effective reproductive number (R_E) at time t is

$$R_E(t) = \frac{\beta+\beta\gamma gV(t,\omega_I)}{\gamma}(1-\varepsilon(1-V(t,\omega_V)))\Omega(t). \tag{S11}$$

Selection of saturation function

We consider six saturation functions that have been widely used in literature (30, 32–35) to be integrated into our model. We fit these six models to past Ebola outbreaks in the DRC (in the absence of conflict) and then determined the best overall saturation function based on its Akaike information criterion (AIC) score

$$\mathrm{AIC} = 2k - 2\log(L_I),$$

where k is the number of estimated parameters and L_I is the likelihood for the weekly Ebola incidence predicted by the model. The Hill function that saturates with respect to cumulative incidence was found to best explain the general trend in Ebola incidence in the past Ebola outbreaks in the DRC (Table S1).

Extension of model

The model is generalizable in regards to the distribution of the latent and infectious period. The use of the

Erlang distribution for the transition rate through states can be critical if implementing a stochastic version of the model or in parameter estimation (36, 37). The model can be readily altered to account for endemic diseases by having the force of infection saturate with respect to prevalence rather than cumulative incidence.

Data

Weekly incidence data

We digitized the incidence from the weekly Ebola incidence curve reported by the World Health Organization (WHO) team for the North Kivu and Ituri Ebola outbreak (38, 39). There was no definitive date as to when vaccination was implemented in North Kivu-Ituri in the general population from the published reports. Vaccination of healthcare workers started August 8 and vaccination in the general community in North Kivu-Ituri possibly started as early as August 12, 2018. A report published on August 12 indicated individuals were being observed (40) and a report published on August 15, 2018 specifies that five rings surrounding 13 confirmed cases had been vaccinated (41).

Conflict data

Any conflict and violent event that was observed outside the outbreak setting, *e.g.* murders, armed attacks, and protests, was used in the qualitative description of the outbreak. This data is the daily conflict data for North Kivu and Ituri from the Armed Conflict Location & Event Data Project (ACLED) dataset for the DRC (42). To quantify the level of conflict at the health zone level, we calculated the number of events that occurred in the health zone as well as those that happened with 10 km of the health zone border. To quantify the level of conflict at the health zone level, we calculated the number of events that occurred in the health zone as well as those that happened within 10 km of the health zone border. This 10 km extension is used to mitigate any inaccuracies regarding the exact location of some of the daily violent events and to include events happening near the border in a neighboring health zone.

Events that had large ramifications for the effectiveness of disease control were explicitly accounted for in the model., *e.g.*, violence towards health care workers or destruction of an Ebola treatment center. To identify these events, we first searched for events targeting Aid workers, health workers, Doctors Without Borders, Red Cross, or those with Ebola in the description. All Ebola related events were kept, but any events associated with aid or healthcare workers that did not occur in an affected Health Zone in North Kivu or Ituri were discarded. We obtained additional information about these specific events from numerous crisis reports (43–47). From this search, we identified 48 critical events from April 30, 2018 to June 25, 2019 (Table S2).

Model fitting

Model parameterization

The average duration and distribution of the latent period should be relatively similar among various Ebola outbreaks. We used the estimate from the 2013-2016 West African outbreak (48), to set the average duration of the latent period ($1/\alpha$) to 9.4 days. The mean value of Erlang distribution for latent period is $1/\alpha$ and the variance is $(1/\alpha)^2 (1/n_E)$ (31). Empirical estimates of the latent period from the West African outbreak were used to determine $n_E = 2$ for the Erlang distribution. This value was obtained by minimizing the difference between Erlang variance (given the empirical estimate of the mean) and empirical estimates of both country-specific (Guinea, Liberia, and Sierra Leone) and aggregated estimates (48). A similar approach was applied to estimate $n_I = 1$ using data from the West African outbreak regarding the time from symptom onset to hospitalization (48). This value for n_I is consistent when it is estimated using time from symptom onset to death from the West African outbreak.

For the extent conflict increases the time to isolation (g), we used the standard deviation from the observed time from symptom onset to hospitalization in the West African outbreak (4.7 days) (48). The

use of this value is based on the assumption that conflict at most would increase the mean time to isolation from symptom onset by at most one standard deviation.

To integrate heterogeneity into the conflict events, we estimated the maximum effect of an event based on which health zone the attack occurred in. To calculate these weights (w_Z), we considered various measures of disease control and determined their variation with respect to the mean, *i.e.* coefficient of variation. The motivation for the use of the coefficient of variation is that it provides information about how much change there is in a given week compared to how well the health zone is doing on average. For example, if a health zone consistently has an inefficient disease control program then conflict is unlikely to change the effectiveness of disease control in the health zone. Whereas, if a health zone experiences a lot of fluctuation relative to the mean then conflict is likely to have an impact on the effectiveness of disease control.

To inform the impact of attacks on the time to isolation (w_Z), we used the weekly reported times to isolation, the percentage of cases that are known contacts, percent of contacts not followed up in last 24 hours, and the percent of investigations completed within 24 hours of a verified alert. For each of these measures, we calculated the coefficient of variation ($CV_{i,z}$) for the Mabalako, Mandima, Beni, Butembo and Katwa, Muessiene, and other affected health zone. To determine the contribution of each of these measures in the weight, we fit a linear regression model using these four measures to the weekly reported aggregated incidence from these Ministère de la santé reports (49–78)

$$Y_t = \beta_0 + \sum_{i=1}^{4} \beta_i X_{t,i}.$$

The coefficients for the time to isolation and percent of contacts not followed up in last 24 hours are positive, as incidence is expected to increase with these measures. Whereas incidence is expected to

decrease with respect to the percentage of cases that are known contacts and percent of investigations completed within 24 hours of a verified alert, indicating negative coefficients. We then computed the weight associated with health zone (Z) as

$$\tilde{w}_Z = \sum_{i=1}^{4} \frac{|\beta_i|}{\sum_{i=1}^{4} |\beta_i|} \frac{CV_{i,Z}}{\max_z CV_{i,z}}. \quad \text{(S12)}$$

Thus, the relative weight associated with health zone (Z) used in the simulation is

$$w_Z = \frac{\tilde{w}_Z}{\max_z \tilde{w}_z}. \quad \text{(S13)}$$

To evaluate the impact of attacks on the effectiveness of vaccination, we utilized data on the percentage of cases that are known contacts, percent of contacts not followed up in last 24 hours, and the percent of investigations completed within 24 hours of a verified alert. We determined the contribution of each measure in the same manner as the time from symptom onset to isolation.

Priors

We informed the prior of the time from symptom onset to isolation in the absence of the effects of conflict ($1/\gamma$), using the data from 2014 Ebola outbreak in the Equateur Province in DRC (79). The average time from symptom onset to hospital admission among 24 cases during this outbreak was 4.69 days, where the standard error was 2.63 days. Thus, we used a uniform prior for the time from symptom onset to isolation to be [2.06, 7.32] days. This time to isolation is consistent with that estimated in the 2018 Equateur outbreak (80).

We treat the inclusions of critical events as a binary vector *a*, to denote whether the event is included. We did not assume that a conflict event necessarily increases incidence. Therefore, each event has a prior of being equally likely to be included and its inclusion or exclusion is determined through the model fitting. The lower bound for the time before an event in which the public health response is impeded (*d*) is seven

days. This bound is based on the increased hostility experienced in the week leading up to the attack of the ETC in Katwa. During the fitting process, we calibrated the bounds for the remaining parameters to improve the efficiency of the Bayesian melding process.

Likelihood

We aim to maximize the log-likelihood

$$L = L_I + L_C, \tag{S14}$$

where L_I is the log-likelihood for the incidence data and L_C is the log-likelihood for the inclusion of events contributing to the inhibition of disease control.

The log-likelihood function for incidence uses a negative binomial distribution and is defined as

$$L_I = \sum_{k=1}^{T_j} \ln\left(\frac{\Gamma\left(r + C_k\right)}{\Gamma\left(r\right)\Gamma\left(1 + C_k\right)}\left(\frac{r}{C(t_k) + r}\right)^r\left(1 - \frac{r}{C(t_k) + r}\right)^{C_k}\right), \tag{S15}$$

where C_k is the weekly incidence for week k, $C(t_k) = C_I(7t_k) - C_I(7(t_k - 1))$ is the model predicted weekly incidence at week t_k based on the cumulative incidence $C_I(\cdot)$, and r is the associated hyperparameter of the negative binomial distribution. During the model fitting, we estimated the events that had long-term effects on disease control (Table S2) by maximizing the log-likelihood

$$L_C = N_A \log\left(\sum_{i=1}^{N_A} \frac{m_{B_i} F_i}{N_A}\right), \tag{S8}$$

where N_A is the number of attacks and $F_i = 1$ if the event impacted disease control, otherwise $F_i = 0$. To simulate the model that incorporates conflict, we used explicit Euler method with a step size of 0.1 days in MATLAB. Furthermore, we tested our results using smaller step sizes of 0.01 and 0.001 and found them to be robust.

Estimates of the effectiveness of disease control

The weekly average value of the effective reproductive number, time to isolation, and effectiveness of vaccination are calculated over the epidemiological week of the reported incidence. We use Riemann sums to approximate the average value of each measure over the epidemiological week.

Table S1: The ΔAIC score for six saturation functions and six Ebola outbreaks in the DRC, where cumulative incidence (C.I.) is denoted by $C_I(t)$ and time by t.

Outbreak	Exp. Decay (C.I.) $\exp\{-KC_I(t)\}$	Exp. Decay (Time) $\exp\{-Kt\}$	Hill (C.I.) $\frac{1}{1+(C_I(t)/K)^n}$	Hill (Time) $\frac{1}{1+(t/K)^n}$	Discount (C.I.) $\frac{1}{(1+K)^{C_I(t)}}$	Discount (Time) $\frac{1}{(1+K)^t}$
Yambuku (1976)	1.19	41.42	5.28	0.00	1.20	41.93
Kikwit (1995)	56.89	90.02	0.00	9.23	51.85	82.23
Mweka (2008)	1.98	4.01	0.15	0.00	1.97	4.00
Isiro (2012)	2.03	0.36	4.75	2.66	1.86	0.00
Boende (2014)	2.47	0.01	0.95	1.05	2.40	0.00
Equateur (2018)	0.61	0.03	3.12	2.93	0.54	0.00
Total	50.94	121.62	0.00	1.62	45.57	113.93

Table S2: The date and description of the attacks on the health care system and the events that inhibited disease control efforts. ETC - Ebola treatment center, HCW- Healthcare worker

Date	Province	Location		Description
24 September 2018	North Kivu	Beni		An ADF attack attributed to at least 19 dead in Beni on September 22, 2019.On September 24, 2019, Beni is declared *ville morte* for five days and Ebola response activities come to a virtual stop
02 October 2018	North Kivu	Butembo		Members of the community attacked two aid workers who were conducting safe Ebola burials
20 October 2018	North Kivu	Butembo		Maï-Maï killed two Ebola healthcare workers
20 October 2018	North Kivu	Beni	Rwenzori	The ADF conducted an attack Rwenzori, an area in Beni, that resulted in at least 12 casualties. This attack was followed by the declaration of *ville morte*.
06 November 2018	North Kivu	Butembo		Health workers peacefully demonstrated denouncing the multiple attacks that they claim to be victims.
27 December 2018	North Kivu	Beni	Lume	Damage to an ETC as a result of the protest for postponing the election
27 December 2018	North Kivu	Beni	Kisima	Damage to an ETC as a result of the protest for postponing the election
27 December 2018	North Kivu	Beni	Bulongo	Damage to an ETC as a result of the protest for postponing the election
27 December 2018	North Kivu	Oicha	Mutwanga	Damage to an ETC as a result of the protest for postponing the election
27 December 2018	North Kivu	Beni		Demonstrations, led by LUCHA, burned tires and ransacked an Ebola facility, causing the patients to flee.
11 January 2019	Ituri	Irumu	Nyakunde	Rocks thrown at healthcare workers, protesting construction of Ebola isolation center in Marabo
24 January 2019	North Kivu	Oicha	Kisiki	ADF ambushed Okapi Logistics non-governmental organization convoy, injuring three and killing three individuals.

05 February 2019	North Kivu	Beni	Vuhovi	Health center in Kasitu attacked by UPLC
11 February 2019	North Kivu	Butembo	Mavono	ETC set on fire.
15 February 2019	Ituri	Mambasa		Residents attack Ebola hand washing station due to anger about the Ebola vaccination campaign and that locals were not hired for the response.
18 February 2019	North Kivu	Beni	Vuhovi	A nurse was abducted from their home and murdered, which prompted health care workers to strike in Vuhovi health zone.
24 February 2019	North Kivu	Oicha	Mamove	A health clinic was burned by an armed group
24 February 2019	North Kivu	Butembo	Katwa	Maï-Maï burned an ETC. Note was left threatening more attacks until elections are held in the area.
27 February 2019	North Kivu	Butembo		Maï-Maï burned an ETC
08 March 2019	North Kivu	Beni	Lubwasi	ADF burned a health clinic
09 March 2019	North Kivu	Butembo		Maï-Maï attacked an ETC
14 March 2019	North Kivu	Lubero	Mamboa	Locals set fire to an ETC and stoned the vehicles of healthcare workers.
22 March 2019	North Kivu	Butembo		An armed group set fire to an ETC
24 March 2019	North Kivu	Butembo		United Nations staff were assaulted, with one of the victims allegedly attacked by family members of an Ebola victim.
25 March 2019	Ituri	Irumu	Bunia	Doctors held protest for inclusion under the risk premium
05 April 2019	North Kivu	Beni	Katiri	HCW attacked while conducting a safe burial
15 April 2019	North Kivu	Butembo		Citizen assaulted by mob due to accusations of spreading Ebola
18 April 2019	North Kivu	Butembo		Priest threatened for allowing an ETC in the Catholic University of Graben
19 April 2019	North Kivu	Butembo		Maï-Maï attacked the ETC in the Catholic University of Graben and killed a Cameroonian doctor
20 April 2019	North Kivu	Butembo	Katwa	ETC in Katwa attacked by unidentified armed group
24 April 2019	North Kivu	Butembo		HCW protest attacks on the ETC

30 April 2019	Ituri	Irumu	Bunia	Attacks during the installation of Ebola sanitation
03 May 2019	North Kivu	Butembo	Bulengera	Altercation during an Ebola burial
07 May 2019	North Kivu	Butembo	Katwa	Hospital in Katwa set on fire
07 May 2019	North Kivu	Beni	Vuhovi	Member of Ebola response team killed
12 May 2019	North Kivu	Butembo	Katwa	Warning shots fired to prevent an attack on ETC, where police killed a man in the process
13 May 2019	North Kivu	Butembo	Katwa	Unidentified militiamen attack an Ebola transit center
14 May 2019	North Kivu	Lubero	Kayna	ETC attacked by residents
25 May 2019	North Kivu	Beni	Vusahiro	ETC attacked and HCW killed
26 May 2019	North Kivu	Butembo		Maï-Maï attacked ETC attacked, where HCW wounded and police officer killed
05 June 2019	North Kivu	Beni		Armed group attacked convoy of HCW treating for Ebola
11 June 2019	Ituri	Irumu	Bunia	Ville morte
13 June 2019	North Kivu	Oicha	Kasindi	Ville morte
13 June 2019	North Kivu	Beni		Ville morte
16 June 2019	Ituri	Irumu	Bunia	ETC burnt
18 June 2019	North Kivu	Beni		Suspected Maï-Maï attempted attack on an ETC
24 June 2019	North Kivu	Beni		Ebola response team attacked
25 June 2019	Ituri	Mambasa	Lukaya	Ebola response team attacked by Maï-Maï

Table S3: Parameter descriptions and values. For parameters estimated from the model fitting, we provide the maximum likelihood estimates and 95% confidence interval.

Parameter	Description	Parameter value	Units	Reference
R_0	Basic reproductive number	1.66 (1.60 - 1.80)		Fitted
$1/\gamma$	Time from symptom onset to isolation in the absence of conflict	6.23 (4.71 - 7.32)	days	Fitted
K	Saturation constant	7.17×10^{-4} (4.35×10^{-4}- 7.30×10^{-4})	cases	Fitted
n	Hill coefficient	2.21 (1.70 - 2.40)		Fitted
r	Hyperparamter for Negative Binomial	24.90 (20.00 - 27.15)	cases	Fitted
ε	Population level effectiveness of vaccination in the absence of conflict	0.520 (0.446 - 0.578)		Fitted
ω_V	Rate effectiveness of vaccination returns to pre-conflict levels	1.51 (1.16 - 1.77)	per day	Fitted
ω_T	Rate time to isolation returns to pre-conflict levels	0.42 (0.35 - 0.52)	per day	Fitted
d	The number of days before the attack in which hostility begins to increase	17 (7 - 20)	days	Fitted
$1/\alpha$	The average duration of the latent period	9.4	days	(48)
n_E	The number of stages for the latent period	2		Estimated
n_I	The number of stages for the infectious period	1		Estimated

Table S4: Estimated values of weights based on location and type of critical events ($m_B w_Z$) for the time from symptom onset to isolation. The estimates for m_B are obtained through model fitting and estimation of w_Z is described in the SI text (*Model parameterization)*.

Type of event	Mabalako	Mandima	Beni	Butembo and Katwa	Musienene	Other
Ville morte	0.84 (0.70-1.00)	0.36 (0.30-0.43)	0.44 (0.37-0.52)	0.43 (0.36-0.51)	0.70 (0.58-0.83)	0.55 (0.46-0.66)
HCW Attack	0.97 (0.91-1.00)	0.42 (0.39-0.43)	0.51 (0.48-0.52)	0.50 (0.47-0.51)	0.81 (0.76-0.83)	0.64 (0.60-0.66)
HCW Protest	0.92 (0.85-1.00)	0.39 (0.36-0.43)	0.48 (0.45-0.52)	0.47 (0.44-0.51)	0.77 (0.71-0.83)	0.61 (0.56-0.66)
ETC attack	1.00 (0.87-1.00)	0.43 (0.37-0.43)	0.52 (0.45-0.52)	0.51 (0.44-0.51)	0.83 (0.72-0.83)	0.66 (0.57-0.66)
Other	0.58 (0.48-0.66)	0.25 (0.20-0.28)	0.30 (0.25-0.34)	0.30 (0.25-0.34)	0.48 (0.40-0.55)	0.38 (0.31-0.43)

Table S5: Estimated values of weights based on location and type of critical events ($m_B w_Z$) for the time from symptom onset to isolation. The estimates for m_B are obtained through model fitting and estimation of w_Z is described in the SI text (*Model parameterization)*.

Type of event	Mabalako	Mandima	Beni	Butembo and Katwa	Musienene	Other
Ville morte	0.75 (0.63-0.90)	0.77 (0.64-0.92)	0.84 (0.70-1.00)	0.54 (0.45-0.65)	0.75 (0.62-0.89)	0.44 (0.37-0.53)
HCW Attack	0.87 (0.81-0.90)	0.89 (0.83-0.92)	0.97 (0.91-1.00)	0.63 (0.59-0.65)	0.87 (0.81-0.89)	0.52 (0.48-0.53)
HCW Protest	0.82 (0.76-0.90)	0.84 (0.78-0.92)	0.92 (0.85-1.00)	0.60 (0.55-0.65)	0.82 (0.76-0.89)	0.49 (0.45-0.53)
ETC attack	0.90 (0.78-0.90)	0.92 (0.79-0.92)	1.00 (0.87-1.00)	0.65 (0.56-0.65)	0.89 (0.77-0.89)	0.53 (0.46-0.53)
Other	0.52 (0.43-0.59)	0.53 (0.44-0.60)	0.58 (0.48-0.66)	0.37 (0.31-0.42)	0.51 (0.43-0.58)	0.31 (0.25-0.35)

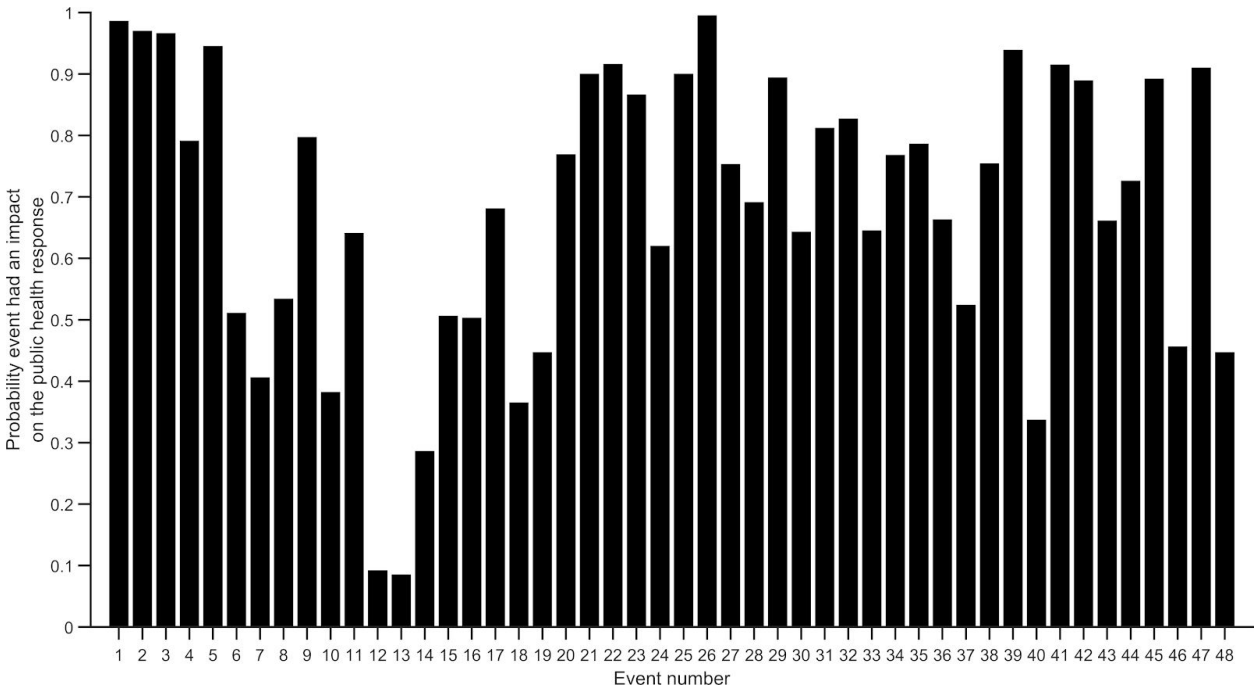

Figure S2: The estimated probability that a critical event impacted the disease control measures during the North Kivu and Ituri outbreak. This probability was estimated from 1000 samples from the Bayesian melding process.

References

1. C.R. Wells et al. The exacerbation of Ebola outbreaks by conflict in the Democratic Republic of the Congo, Available at https://github.com/WellsRC/The-exacerbation-of-Ebola-outbreaks-by-conflict-in-the-Democratic-Republic-of-the-Congo. *GitHub* (2019).

2. , "Ebola Virus Disease: Democratic Republic of the Congo: External Situation Report" (World Health Organization, 2018) (April 2, 2019).

3. , Years of Ebola Virus Disease Outbreaks | 2014-2016 Outbreak West Africa | History | Ebola (Ebola Virus Disease) | CDC (2018) (April 2, 2019).

4. , "Ebola Virus Disease: Democratic Republic of the Congo: External Situation Report" (World Health Organization, 2019) (April 2, 2019).

5. , WHO | Ebola virus disease – Democratic Republic of the Congo (2019) (June 17, 2019).

6. , "Ebola Virus Disease: Democratic Republic of the Congo: External Situation Report" (World Health Organization, 2018) (April 16, 2019).

7. C. R. Wells, *et al.*, Ebola vaccination in the Democratic Republic of the Congo. *Proc. Natl. Acad. Sci. U. S. A.* (2019) https:/doi.org/10.1073/pnas.1817329116.

8. J. Cohen, Congo's Ebola outbreak is all but over. Did an experimental vaccine help? *Science* (2018) https:/doi.org/10.1126/science.aau8236.

9. J. Cohen, Ebola vaccine is having "major impact" but Congo outbreak may still explode. *Science* (2018) https:/doi.org/10.1126/science.aaw3395.

10. A. Green, DR Congo Ebola virus treatment centres attacked. *Lancet* **393**, 1088 (2019).

11. B. Moran, Fighting Ebola in conflict in the DR Congo. *Lancet* **392**, 1295–1296 (2018).

12. The Lancet, DR Congo: managing Ebola virus in war. *Lancet* **392**, 1280 (2018).

13. E. Nakkazi, DR Congo Ebola virus outbreak: responding in a conflict zone. *The Lancet* **392**, 623 (2018).

14. A. Maxmen, Violence propels Ebola outbreak towards 1,000 cases. *Nature* **567**, 153–154 (2019).

15. Deutsche Welle (www. dw.com), Opinion: Ebola in Congo — incompetence, mistrust and greed | DW | 01.08.2019. *DW.COM* (August 1, 2019).

16. B. McPake, *et al.*, Ebola in the context of conflict affected states and health systems: case studies of Northern Uganda and Sierra Leone. *Confl. Health* **9** (2015).

17. M. Gayer, D. Legros, P. Formenty, M. A. Connolly, Conflict and Emerging Infectious Diseases. *Emerg. Infect. Dis.* **13**, 1625 (2007).

18. T. Crellen, *et al.*, What drives mortality among HIV patients in a conflict setting? A prospective cohort study in the Central African Republic https:/doi.org/10.1101/437103.

19. J. Kennedy, A. Harmer, D. McCoy, The political determinants of the cholera outbreak in Yemen. *Lancet Glob Health* **5**, e970–e971 (2017).

20. M. Fallah, L. A. Skrip, E. d'Harcourt, A. P. Galvani, Strategies to prevent future Ebola epidemics. *Lancet* **386**, 131 (2015).

21. D. Mclean, "Impact of violence on medical and humanitarian services in North Kivu, DRC" (Analysis Department, MSF, Brussels, 2017) (May 14, 2019).

22. K. Büscher, Urbanisation and the Political Geographies of Violent Struggle for Power and Control : Mining Boomtowns in Eastern Congo. *Revue internationale de politique de développement* **10 | 2018**, 302–324 (2018).

23. H. Matfess, Layered Insecurity in North Kivu: Violence and the Ebola Response | Acled Data. *Acled Data* (2018) (March 28, 2019).

24. , Data Export Tool | Acled Data. *Acled Data* (April 12, 2019).

25. J. Bedford, "Key considerations: the context of North Kivu province, DRC" (Social Science in Humanitarian Action) (March 29, 2019).

26. , ISIS Claims First Attack in the Democratic Republic of Congo (2019) (April 22, 2019).

27. E. Buckingham-Jeffery, V. Isham, T. House, Gaussian process approximations for fast inference from infectious disease data. *Math. Biosci.* **301**, 111–120 (2018).

28. S. Cauchemez, N. M. Ferguson, Likelihood-based estimation of continuous-time epidemic models from time-series data: application to measles transmission in London. *J. R. Soc. Interface* **5**, 885–897 (2008).

29. L. J. S. Allen, A primer on stochastic epidemic models: Formulation, numerical simulation, and analysis. *Infect Dis Model* **2**, 128–142 (2017).

30. D. N. Fisman, T. S. Hauck, A. R. Tuite, A. L. Greer, An IDEA for short term outbreak projection: nearcasting using the basic reproduction number. *PLoS One* **8**, e83622 (2013).

31. O. Krylova, D. J. D. Earn, Effects of the infectious period distribution on predicted transitions in childhood disease dynamics. *J. R. Soc. Interface* **10**, 20130098 (2013).

32. A. J. Kucharski, *et al.*, Measuring the impact of Ebola control measures in Sierra Leone. *Proc. Natl. Acad. Sci. U. S. A.* **112**, 14366–14371 (2015).

33. R. M. Granich, C. F. Gilks, C. Dye, K. M. De Cock, B. G. Williams, Universal voluntary HIV testing with immediate antiretroviral therapy as a strategy for elimination of HIV transmission: a mathematical model. *Lancet* **373**, 48–57 (2009).

34. A. Camacho, *et al.*, Potential for large outbreaks of Ebola virus disease. *Epidemics* **9**, 70–78 (2014).

35. A. H. Talal, *et al.*, Pharmacodynamics of PEG-IFN α differentiate HIV/HCV coinfected sustained virological responders from nonresponders. *Hepatology* **43**, 943–953 (2006).

36. C. A. A. Beauchemin, T. Miura, S. Iwami, Duration of SHIV production by infected cells is not exponentially distributed: Implications for estimates of infection parameters and antiviral efficacy. *Scientific Reports* **7** (2017).

37. O. Krylova, D. J. D. Earn, Effects of the infectious period distribution on predicted transitions in childhood disease dynamics. *J. R. Soc. Interface* **10**, 20130098 (2013).

38. , "Ebola Virus Disease: Democratic Republic of the Congo: External Situation Report" (World Health Organization, 2018) (March 20, 2019).

39. , "Ebola Virus Disease: Democratic Republic of the Congo: External Situation Report" (World Health Organization, 2019) (March 20, 2019).

40. , "Ebola Virus Disease: Democratic Republic of the Congo: External Situation Report" (World Health Organization, 2018) (April 1, 2019).

41. , WHO | Ebola virus disease – Democratic Republic of the Congo (2018) (April 1, 2019).

42. , Data Export Tool | Acled Data. *Acled Data* (April 12, 2019).

43. , Safeguarding Healthcare Monthly News Brief - Attacks on healthcare, February 2019 - World. *ReliefWeb* (April 12, 2019).

44. , DRC Ebola outbreak crisis update | Médecins Sans Frontières (MSF) International. *Médecins Sans Frontières (MSF) International* (April 12, 2019).

45. , Safeguarding Healthcare Monthly News Brief - Attacks on healthcare, January 2019 - World. *ReliefWeb* (April 12, 2019).

46. , Safeguarding Healthcare Monthly News Brief - Attacks on healthcare, December 2018 - World. *ReliefWeb* (April 12, 2019).

47. , "Northeast DRC Ebola Outbreak: Crisis Info" (Médecins Sans Frontières , 2019) (April 12, 2019).

48. W. E. R. Team, WHO Ebola Response Team, Ebola Virus Disease in West Africa — The First 9 Months of the Epidemic and Forward Projections. *New England Journal of Medicine* **371**, 1481–1495 (2014).

49. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 25 : du 17 au 23 juin 2019).

50. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 24 : du 10 au 16 juin 2019).

51. , "RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 48 : du 26 nov au 02 déc. 2018)" (Ministère de la santé, OMS et Partenaires).

52. (semaine 23 :. du 03 au 09 juin 2019), RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 23 : du 03 au 09 juin 2019).

53. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 22 : du 27 mai au 02 juin 2019).

54. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 21 : du 20 au 26 mai 2019).

55. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 20 : du 13 au 19 mai 2019).

56. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 18 : du 29 avril au 05 mai 2019).

57. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 17 : du 22 au 28 avril 2019).

58. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 19 : du 06 au 12 mai 2019).

59. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 16 : du 15 au 21 avril 2019).

60. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 15 : du 08 au 14 avril 2019).

61. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 14 : du 01 au 07 avril 2019).

62. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 13 : du 25 au 31 mars 2019).

63. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 12 : du 18 au 24 mars 2019).

64. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 11 : du 11 au 17 mars 2019).

65. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 09 : du 25 février au 03 mars 2019).

66. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 10 : du 04 au 10 mars 2019).

67. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 06 : du 04 au 10 février 2019).

68. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 08 : du 18 au 24 février 2019).

69. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 04 : du 21 au 27 janvier 2019).

70. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 50 : du 10 au 16 déc. 2018).

71. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 01 : du 31 décembre 2018 au 06 janvier 2019).

72. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 48 : du 26 nov. au 02 déc. 2018).

73. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Per formance de la riposte à la Maladie à Virus Ebola (Semaine 49 : du 03 au 09 déc. 2018).

74. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 05 : du 28 janvier au 03 février 2019).

75. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 03 : du 14 au 20 janvier 2019).

76. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 02 : du 07 au 13 janvier 2019).

77. O. et P. Ministère de la santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 51 : du 17 au 23 déc. 2018).

78. M. de la Santé, RD Congo - Ituri et Nord-Kivu : Suivi des Indicateurs Clés de Performance de la riposte à la Maladie à Virus Ebola (Semaine 07 : du 11 au 17 février 2019).

79. C. Nanclares, *et al.*, Ebola Virus Disease, Democratic Republic of the Congo, 2014. *Emerg. Infect. Dis.* **22**, 1579–1586 (2016).

80. Ebola Outbreak Epidemiology Team, Outbreak of Ebola virus disease in the Democratic Republic of the Congo, April-May, 2018: an epidemiological study. *Lancet* **392**, 213–221 (2018).