BIOMEDICAL SCIENCE JOURNAL FOR TEENS

AUGUST 2018

How deadly is Ebola?

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Abstract

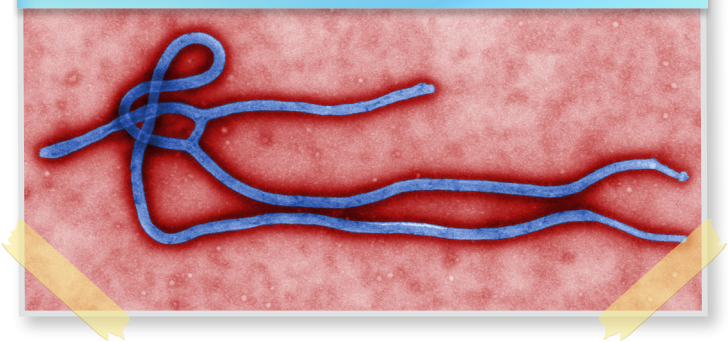
Have you ever heard of Ebola? Of course you have. It's one of the scariest diseases out there. And one of the deadliest. It kills between 44 and 90 percent of the people it infects. Why is there such a big range? What makes some Ebola infections deadlier than others? To answer these questions, we analyzed thousands of Ebola cases reported during the 2013-2016 Ebola outbreak in West Africa. We wanted to know what factors helped some of the patients survive. We found that age is a really important factor determining if the patient survived or not. That is because young adults are more likely to survive than others. We also analyzed the proportion of patients who survived by district and by hospital and found that these proportions did not always match our expectations: they were either a lot higher or a lot lower.

Introduction

Ebola is one of the world's most feared diseases. Not only are its symptoms really serious but there also is no cure. Ebola has killed between 44 to 90 percent of the people it infects. This proportion of people who die from a disease among everyone who got sick with it is called the *case fatality ratio* (CFR). Why is this measure important? It doesn't only assess the severity of the virus (or other pathogens); it also helps with planning *disease control* efforts and new *treatment evaluation*.

During the Ebola outbreak in West Africa, which was the largest by far in history, the three most affected countries Sierra Leone, Guinea and Liberia reported 28,616 *confirmed, probable and suspected* cases and 11,310 deaths. Throughout this outbreak CFR estimates have varied greatly. Why? Which factors influence mortality? These were the questions we wanted to answer.

Figure 1: A greatly enlarged view of the Ebola virus (Source: US CDC)



For the curious:

There are 5 different viruses which cause Ebola (for one of them see Figure 1). The most severe and the one which caused the West Africa outbreak is the *Zaire ebolavirus*. You can only get infected through close contact with blood or other bodily fluids of a sick person or infected animal. Once infected, symptoms appear 2 - 21 days later and include high fever, muscle pain, diarrhea, vomiting, bleeding inside and outside of the body, and others - though not every patient has every one of these symptoms.

Methods

We analyzed data on thousands of Ebola cases reported officially to the World Health Organization (WHO) during the 2013-2016 Ebola outbreak in West Africa (Figure 2). These data included information such as age, sex, district where they patient lived, when the symptoms appeared, clinical outcome (did the patient survive or not), and if the patient was in a hospital or not. To get more reliable results, we analyzed only the confirmed cases (excluding probable and suspected cases).

Using statistical models, we investigated the effect of these factors, such as age and sex, on clinical outcomes to find out what makes Ebola more dangerous.

We also analyzed CFR by district and by hospital to search for any *outliers* (unusually high or low CFRs compared to what we expected). To predict the CFR for each district or hospital, we created mathematical models. We then compared our modelled results with the actual observed CFR and looked for any significant differences. We also adjusted the models to account for the variety of cases (taking into account different age groups, date of the onset of symptoms, etc.).

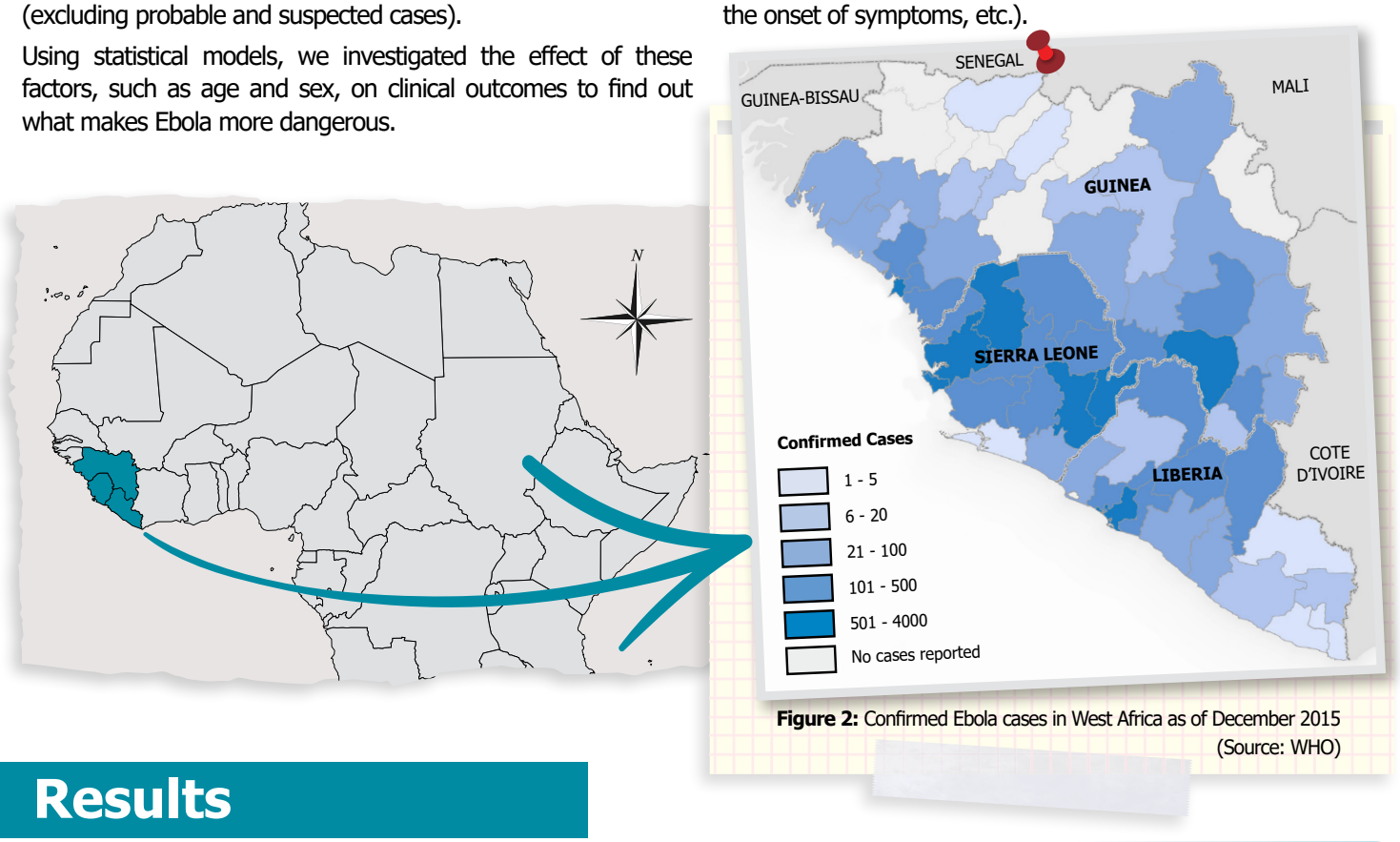


Figure 2: Confirmed Ebola cases in West Africa as of December 2015 (Source: WHO)

Results

- The overall CFR among the 8413 confirmed cases in the three West-African countries was 63%.
- Age had a big influence on mortality: Cases among teenagers and young adults had best chances of survival, while children under 5 and elderly over 75 were at greatest risk of dying (showed highest CFR) (see Figure 3).
- Hospitalization was another significant factor influencing mortality. As much as 93% of the patients who were not in a hospital died of the disease.
- When comparing the overall average CFR with the observed CFR (the proportion of patients that actually died) in each district or hospital, we identified 14 of 43 districts and 18 of 66 hospitals which showed significant differences. After we took the various cases' factors into account, 8 out of 43 districts and 3 of 66 hospitals still showed differences.

What age group has the biggest chances of survival?

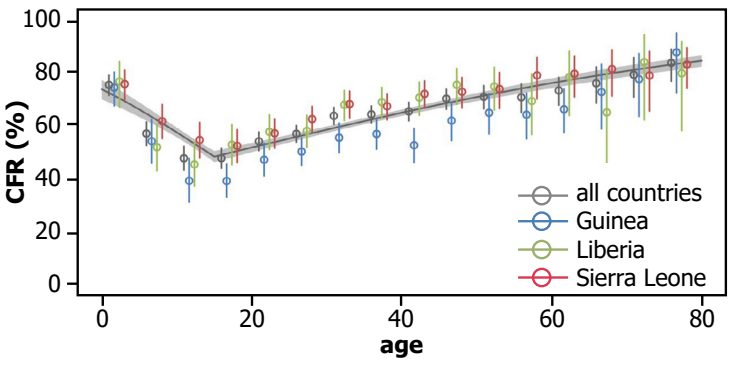


Figure 3: Case Fatality Ratio (CFR) by age of Ebola patients in three West-African countries.

Discussion

Estimating the CFR may seem like an easy task but it's surprisingly difficult during outbreaks. This is when things can get inaccurate because of various *biases*. For example, *burial teams* (Figure 4) mostly identify fatal cases and people are more likely to report more severe cases, which results in a bias towards death and higher CFR in our data than we would have seen had every single case been recorded.

Patients with more severe symptoms are also more likely to seek hospital care.

On the other hand, keeping in mind it's a very serious disease we are talking about, patients are not always able to reach a hospital before they die, which could make the estimate of CFR too low. We tried to reduce these inaccuracies by excluding cases for which the clinical outcome was already clear on the date of reporting.

Mortality depended on age in all three countries, which makes us confident it's a real biological effect (though we have to consider whether the same pattern of bias with age could have occurred in all three countries). Although we found differences in CFR between hospitalized and non-hospitalized cases as well, we cannot conclude this is due to clinical care.

Indeed, there is no specific treatment yet for Ebola, only managing symptoms. There could be other reasons for these differences, such as the quick death of some patients (before they can reach a hospital); or the fact that people's reports are not as thorough as hospitals'.

The predicted CFR for each district and hospital varied greatly from the average CFR across all districts or hospitals. Even after we took the specific cases and their factors into account, quite a few of the districts still showed significantly lower or higher CFR than we expected. The adjusted model, though, was able to explain much of the variation in the CFR between hospitals. This suggests that variation in clinical care from hospital to hospital was not such an important factor for survival.

Figure 4: An Ebola burial team handling Ebola victims. (Source: UNMEER)

Conclusion

Our study showed us that it is important to look both at the details and the big picture when trying to make conclusions because sometimes obvious interpretations may be inaccurate. This is why we cannot determine whether the variation in CFR by district or hospital is related to the quality of health care or other factors.

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Glossary of Key Terms

Bias - a pattern in data collection which prevents an objective view of a situation.

Burial teams – teams responding to death alerts and trained in how to handle the body of Ebola victims in a way that was both safe and approved by cultural and religious leaders. (In the beginning of the outbreak many people got infected with Ebola virus during funerals and burials.)

Case fatality ratio (CFR) - proportion of people who die from a disease among everyone who got sick; for example, bubonic plague (untreated) has a CFR of ~60%, which means out of a hundred infected people, on average 60 would die.

Confirmed, probable, suspected cases:

- **suspected case:** any person with the symptoms but no laboratory confirmation;
- **probable case:** any person with symptoms and known exposure to the infection, or a clinician has evaluated the patient;
- **confirmed case:** any person with laboratory confirmation.

Disease control - different measures authorities and people take to prevent the spread of some diseases. For example, to control malaria we can avoid being bitten by mosquitoes; avoid leaving stagnant water where mosquitoes can breed; ensure fast diagnosis etc.

Ebola (Ebola virus disease, formerly known as **Ebola hemorrhagic fever)** - an often deadly disease for humans and other mammals that is caused by the Ebola virus.

Outlier - something that is notably different from the rest of the group.

Treatment evaluation – assessment of the effectiveness of medical care. For example, if there is a new effective cure for Ebola, the CFR will be lower than usual.

Check your understanding

1. If everyone dies of a disease (for example untreated and unvaccinated rabies), what is the CFR? What about 4 out of 50 people?
2. According to our study, what is the main factor determining the severity of Ebola?
3. Burial teams are a form of disease control. Why do you think that is?
4. If CFR of Ebola is similar among different hospitals, what does this say about medical care?
5. Can you think of any other infectious diseases with high CFR if left untreated?