



Cholera in Yemen — An Old Foe Rearing Its Ugly Head

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Yemen, a country with a population of approximately 25 million located at the southern tip of the Arabian Peninsula, is now experiencing one of the largest cholera outbreaks in recent history.

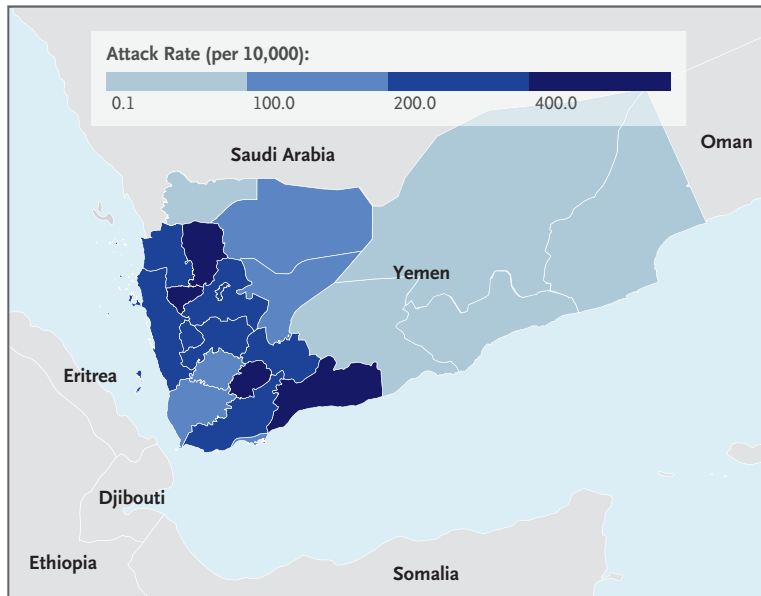
The outbreak, which began in late October 2016 and is reportedly due to *Vibrio cholerae* O1, serotype Ogawa, followed on the heels of civil conflict between Houthi rebels and the internationally recognized Yemeni regime. Beginning in the capital, Sana'a, it spread rapidly, and by December 2016, cases had been reported in 15 of the country's 22 governorates and municipalities. The outbreak appeared to be in decline by March 2017, when a cold wave hit the country, but it resurged dramatically in April (see map), coincident with heavy rains that may have contaminated drinking water sources, and was amplified by war-related destruction of municipal water and sewage systems. In September, the World Health

Organization (WHO) announced that there have been about 700,000 cases and more than 2000 deaths from cholera (in addition to the 10,000 other deaths caused by the conflict), and the epidemic had spread to all governorates and municipalities except one.¹ Although the epidemic seems to be slowing again somewhat, 5000 suspected cholera cases were still being reported every day as of late September.

Even before the conflict, Yemen was among the poorest of the Arab countries, beset by circumstances that made it ripe for cholera, a waterborne disease with fecal-oral transmission. Afflicted by droughts and a lack of water, it was considered among the most water-stressed coun-

tries in the world. According to WHO-UNICEF statistics, in 2014 only 53% of the population used improved sanitation facilities and only 55% had access to drinking water from improved water sources.² Since the onset of the conflict, the situation has worsened markedly. Millions of people have been displaced and now live under conditions with inadequate shelter, water, sanitation, and food. Delivery of health care has been limited by the destruction by air strikes of approximately half the health sector facilities, including hospitals and clinics. In addition, about 30,000 health care workers have not received their salaries during the past year, and many have fled the country.

A naval and air blockade of rebel-controlled areas has contributed to shortages of food, fuel, and medical supplies. Bombing has destroyed water and sanitation infrastructure in some areas, and many sanitation workers have been



Cholera Attack Rate in the Governorates of Yemen, 2017.

Data are as of October 1 and are from the *Yemen: Cholera Response Weekly Epidemiological Bulletin*, World Health Organization (www.emro.who.int/images/stories/yemen/Yemen_-_Cholera_Response_-_Week_39_2017_1.pdf).

on strike for several months. A massive fuel shortage has led to the disruption of sewage management and wastewater treatment facilities and a lack of electricity to run water pumps. The WHO has estimated that approximately 15 million people lack access to basic health care and potable water and sanitation. At least 17 million face food insecurity, 7 million are at risk for famine, and 2 million children are malnourished.

Considering the extremely hazardous conditions and other major challenges in this war-ravaged country, the WHO, UNICEF, other international agencies, nongovernmental organizations, and Yemeni health care providers have mounted an extraordinary response and have limited the overall case fatality rate of reported cholera cases to a relatively low 0.5%.³ These organizations have also made efforts to supply chlorinated water,

restore the operationalization of water-treatment plants, provide hygiene kits with soap and chlorination tablets, and provide training in water-sanitation-hygiene behaviors to help prevent cholera. Yet, as Tedros Adhanom Ghebreyesus, the WHO director-general, recently emphasized, “Yemen’s health workers are operating in impossible conditions. Thousands of people are sick, but there are not enough hospitals, not enough medicines, not enough clean water. These doctors and nurses are the backbone of the health response — without them we can do nothing in Yemen. They must be paid their wages so that they can continue to save lives.”⁴

Inactivated vibrio whole-cell oral cholera vaccines (OCVs), given as a two-dose regimen, are now internationally accepted as tools for the control of epidemic and endemic cholera. A global stockpile of these vaccines, managed

by the International Societies of the Red Cross and Red Crescent, UNICEF, the WHO, and Doctors without Borders (Médecins sans Frontières), with the WHO as the secretariat, and funded by Gavi, the Vaccine Alliance, has been in operation since 2013. This stockpile has largely been allocated for the control of epidemics and for use in humanitarian crises, and to date it has been deployed in cholera outbreaks in Africa, Asia, Haiti, and the Middle East. In late June 2017, a request was made on behalf of Yemen for 3.4 million doses, and the decision was made to release 1 million doses — at the time the most doses ever to be deployed from the stockpile in its 4-year history. However, several weeks later, a meeting in Sana’a of local ministries as well as United Nations and other aid agencies resulted in retraction of the request for vaccine. Various aid agencies have been quoted by the media explaining that resources would be better spent on existing preventive and therapeutic approaches to the epidemic, that mass immunization would be logistically difficult in this setting, and that the impact of vaccination would be minimal because the epidemic had spread so widely.

No one has a better sense of the challenges in logistics and safety of conducting a mass immunization campaign than workers on the ground. And it is undoubtedly true that the request for vaccination came late; had vaccination been implemented earlier, it might have been helpful in containing the epidemic. It’s possible, however, that it was not too late in the epidemic for vaccination to help: experience has demonstrated that deployment of

OCV, reactively, in epidemics can be effective.⁵ And if the current case count is reliable, we may estimate that roughly 7 million to 14 million people, in a population of 25 million, have been infected. Yet admittedly, a million doses would probably be far too few to have a major impact in controlling the entire country-wide epidemic. Plans are reportedly being discussed for a much more massive allocation of doses for a mass immunization program at a later date.

Though we have not been directly involved in the public health response to this outbreak, we can offer a few general observations. First, Yemen before the epidemic, like Haiti before its ongoing epidemic, had a profile in terms of water, sanitation, and hygiene that made it extremely vulnerable to a cholera epidemic on the heels of a humanitarian emergency. When we think of the geographic reach of cholera, we should recognize

not only places that report cases of the disease but also places that are at high risk for it.

Second, although prior to this epidemic Yemen had not reported cholera since the 1980s, the magnitude of this epidemic and the evisceration of the country's infrastructure by the war place Yemen at high risk for continued endemic cholera in the future, much as appears to have happened in Haiti, where a massive cholera epidemic occurred in 2010 after approximately 100 years without cholera.

Finally, despite important efforts by the WHO and other international organizations to create and deploy the OCV global stockpile, that stockpile is currently inadequate. Moreover, we lack validated predictive tools to identify humanitarian emergencies posing so high a risk of cholera that the doses of OCV should be deployed preemptively, as well as tools to flag incipient outbreaks

that are destined to become so large that doses should be deployed early. Greater funding for the stockpile and more work on the development of both improved predictive tools and improved water and sanitation are important priorities.

Disclosure forms provided by the authors are available at NEJM.org.

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Optimizing GME by Measuring Its Outcomes

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U.S. graduate medical education (GME) is a high-stakes enterprise, expected to produce a continuous supply of physicians capable of delivering excellent care, advancing the science and delivery of health care, and preparing those who will later fill their shoes. How do we know if we're hitting the mark?

Unfortunately, no system exists to track how well GME's goals are being achieved. Recent reports have called for substantial reform of its content, structure, governance, and financing.^{1,2} It

is difficult, however, to address concerns about GME without reliable, systematic data. Notable changes such as competency-based curricula and duty-hour limits have been implemented, but a more substantial overhaul of GME's design and delivery remains elusive.

In 2014, a committee of the Institute of Medicine (now the National Academy of Medicine) recommended that federal funding be used as a lever to enhance GME, but the lack of outcomes data presented a barrier to devel-

oping specific policy proposals.² Moreover, a dearth of consistent GME metrics hampers assessment of educational interventions. Outcomes data would not only help to document the return on taxpayers' \$15-billion-plus annual investment in GME (which is repeatedly threatened) but would also pave the way for improving that return. Assessment of the impact of individual graduates, the performance of programs, and the collective contribution of our GME "system" would help inform policy decisions and fa-