Cholera Prevention With Traditional and Novel Water Treatment Methods: An Outbreak Investigation in Fort-Dauphin, Madagascar

| Megan E. Reller, MD, Yves J.M. Mong, MSc, Robert M. Hoekstra, PhD, and Robert E. Quick, MD, MPH

In March 1999, cholera appeared in Madagascar after a long hiatus and caused more than 37 000 cases and 2200 deaths. In October 1999, the Cooperative for Assistance and Relief Everywhere (CARE) and the Centers for Disease Control and Prevention (CDC) Health Initiative funded CARE Madagascar to implement a household-based safe water intervention. CARE contracted with Population Services International to socially market a sodium hypochlorite solution, named Sûr'Eau. In February 2000, cholera reached the southern port city of Fort-Dauphin. Sûr'Eau was introduced to the region in December 2000; cholera peaked in January 2001 in Fort-Dauphin. We conducted a case–control study to investigate risk factors for cholera transmission from February 11 to 20, 2001.

Cases were selected from 113 patients registered at the Cholera Treatment Center of Hôpital Philibert Tsiranana. We defined a case of suspected cholera as 3 or more watery stools per 24 hours in a person 12 years or older who was hospitalized at the Cholera Treatment Center between January 1 and February 7, 2001, resided in Fort-Dauphin, and was the primary household case patient. For each case, we selected 2 age- (±5 years), sex-, and neighborhood-matched control subjects from households free of diarrhea during the outbreak. We interviewed patients about symptoms and treatment received and queried patients and control subjects about beverages and foods consumed in the 5 days before the patient's illness. We cultured stool samples from patients at the Cholera Treatment Center.

We analyzed water quality data obtained by CARE from 12 public taps and 61 randomly selected households in December 2000. Samples were tested for free and total chlorine residuals and for *Escherichia coli* with the membrane filtration technique.[1]

We performed univariate and multivariate analysis, including conditional logistic regression, to determine independent risk factors for infection.

We excluded 76 of the 113 patients for the following reasons: not found (24), lived outside of Fort-Dauphin (20), younger than 12 years (17), died (6), incarcerated (5), and secondary cases (4). The median age of the 37 remaining patients was 37 years (range= 12–64 years); 46% were female. Eleven (30%) patients were illiterate, compared with 11 (15%) of the 74 control subjects (P=.09).

The median duration of illness was 3 days (range=1–7 days). Symptoms included diarrhea (100%), vomiting (78%), and leg cramps (68%). Oral rehydration solution and intravenous fluids were given to 92% of the patients, and oral rehydration solution only was given to 8%. All received doxycycline.

Water sources included a public tap for 78 (70%) of the 111 respondents, household taps for 21 (19%), shallow wells for 10 (9%), and a river or lake for 2 (2%). Of the 106 respondents who stored water, 103 (97%) used a bucket, 2 (2%) a jerry can, and 1 (0.9%) a clay pot. Overall, 52 (49%) covered their water vessel; 100 (94%) removed water from the vessel with a ladle or cup, 4 (4%) removed water by pouring, and 2 (2%) did both. Water sources and handling practices did not differ between cases and controls.

Patients were more likely than control subjects to have drunk untreated water (matched odds ratio [OR]=5.0; 95% confidence interval [CI]=1.3, 25.4; Table 1). Drinking heated rice water (a traditional drink prepared after meals by heating water with remaining grains of rice) or water from a household tap was protective against cholera (OR=0.1; 95% CI=0.0, 0.6 and OR=0.1; 95% CI=0.0, 0.9, respectively), whereas drinking cold rice water was not. Using Sûr'Eau or always boiling water tended to be protective (Table 1).

Illness was not associated with consuming lemonade, unwashed produce, cold leftover rice, or foods or beverages from street vendors (Table 1). Consuming chicken, eggs, milk, or leftover rice was protective. Using soap to wash hands was protective against illness (OR=0.2; 95% CI=0.0, 0.7).

In a multivariate model that controlled for the differences in diet between patients and control subjects, illness was independently associated with consuming untreated water or a food or beverage on a trip outside Fort-Dauphin (P<.05). Drinking heated rice water was protective (P<.05). Although the protective effect of Sûr'Eau was not statistically significant in the multivariate model because of small numbers, the estimated effect was highly protective (OR=0.1), was equivalent in magnitude to rice water, and persisted in different analytic models.

Three stool samples yielded toxigenic *Vibrio cholerae* O1, biotype El Tor, serotype Ogawa, which was resistant to doxycycline. Nine of the 12 public water taps sampled had free chlorine residuals of 0.2 mg/L or higher; 1 yielded *E coli*. Of the 61 stored water samples, 9 (15%) had free chlorine residuals of 0.2 mg/L or higher, and 42 (69%) yielded *E coli*.

In this investigation, we implicated untreated water as the principal vehicle of epidemic cholera in Fort-Dauphin. The community was at risk for waterborne illness despite having access to piped water. Possible reasons for increased risk included inconsistent chlorination of municipal water and domestic storage in wide-mouthed buckets, which permitted hands to touch, and contaminate, stored drinking water.[2,3] Not using soap to wash hands increased the risk of cholera. Improving access to narrow-mouthed containers with covers[4,5] and to soap would reduce the risk of disease.

Increased access to point-of-use water treatment options also is needed, as evidenced by the protective effect of 3 interventions—rice water; a household tap, which eliminated the need for storage; and Sûr'Eau. The protective effect of Sûr'Eau, although consistently high in different multivariate models, did not reach statistical significance only because of small numbers.

Unlike many investigations,[6] this study did not implicate specific food items as risk fac-

TABLE 1—Number (%) of Cholera Case Patients and Control Subjects Exposed to Food and Drink Items: Fort-Dauphin, Madagascar, February 2001

Exposure	Case Patients (%)	Control Subjects (%)	OR	95% CI	*P*
Untreated water, any source	32/36 (88.9)	49/73 (67.1)	5.0	1.3, 25.4	.02
Boiled water	24/37 (64.9)	60/74 (81.1)	0.4	0.1, 1.1	.09
Water treated with Sûr'Eau[a]	1/37 (2.7)	11/74 (14.9)	0.1	0.0, 1.2	.11
Heated rice water	27/36 (75.0)	71/74 (95.9)	0.1	0.0, 0.6	.004
Cold rice water	18/26 (69.2)	55/71 (77.5)	0.6	0.1, 2.2	NS
Water from home faucet	3/37 (8.1)	18/74 (24.3)	0.1	0.0, 0.9	.04
Beverage outside of home	21/36 (58.3)	49/73 (67.1)	0.7	0.2, 1.9	NS
Lemonade	9/37 (24.3)	17/74 (23.0)	1.1	0.4, 3.1	NS
Stored water touched by hand	19/36 (52.8)	29/70 (41.4)	1.8	0.7, 5.4	NS
Water stored in covered container	22/36 (61.1)	33/70 (47.1)	3.3	0.6, 15.0	NS
Food or beverage in market	15/37 (40.5)	29/74 (39.2)	1.1	0.4, 2.6	NS
Food or beverage from street vendor	15/37 (40.5)	31/74 (41.9)	0.9	0.3, 2.5	NS
Food or beverage during trip outside Fort-Dauphin	6/37 (16.2)	5/74 (6.8)	2.8	0.6, 13.2	NS
Meat or fish	36/37 (97.3)	72/72 (100)	Undefined	Undefined	NS
Beef	10/37 (27.0)	16/72 (22.2)	1.5	0.5, 4.9	NS
Chicken	2/37 (5.4)	17/72 (23.6)	0.1	0.0, 0.8	.03
All meat	27/37 (73.0)	60/74 (81.1)	0.6	0.2, 1.8	NS
Shellfish	17/37 (45.9)	28/74 (37.8)	1.4	0.6, 3.3	NS
Eggs	0/37 (0)	20/74 (27.0)	Undefined	Undefined	.002
Milk	6/37 (16.2)	29/74 (39.2)	0.3	0.1, 0.9	.03
Fruit	31/37 (83.8)	70/74 (94.6)	0.3	0.1, 1.4	.13
Vegetables	5/37 (13.5)	20/74 (27.0)	0.4	0.1, 1.3	NS
Unwashed produce	15/37 (40.5)	23/74 (31.1)	0.5	0.6, 3.4	NS
Leftover rice	16/35 (45.7)	54/74 (73.0)	0.3	0.1, 0.8	.015
Unheated leftover rice	5/16 (31.3)	12/54 (22.2)	6.5	0.5, 295.4	NS
Using soap to wash hands	9/37 (24.3)	37/74 (50.0)	0.2	0.0, 0.7	.008

Note. NS = not significant.
[a]Socially marketed 0.5% sodium hypochlorite solution.

tors, but the multivariate model did show the risk of consuming foods or beverages during travel outside of Fort-Dauphin. The protective effect of consuming chicken, eggs, or milk, all expensive in Fort-Dauphin, was likely a surrogate for relatively higher socioeconomic status.

In much of the developing world, delivery of consistently disinfected, piped water will remain out of reach for many households in the foreseeable future because of limited resources.[7] Inexpensive point-of-use treatment and safe storage interventions that are currently available can reduce the risk of disease now. ■

About the Authors

Megan E. Reller and Robert E. Quick are with the Foodborne and Diarrheal Diseases Branch, Division of Bacterial and Mycotic Diseases, Centers for Disease Control and Prevention, Atlanta, Ga. Yves J.M. Mong is with the Centre National de Récherches sur l'Environnement, Antananarivo, Madagascar. Robert M. Hoekstra is with the Biostatistics and Information Management Branch, Division of Bacterial and Mycotic Diseases, Centers for Disease Control and Prevention, Atlanta, Ga.

Requests for reprints should be sent to Megan E. Reller, MD, Foodborne and Diarrheal Diseases Branch, Mailstop A38, Centers for Disease Control and Prevention, Atlanta, GA 30333 (e-mail: mhr6@cdc.gov).

This brief was accepted June 5, 2001.

Note. Use of trade names is for identification only and does not constitute endorsement by the Centers for Disease Control and Prevention or by the US Department of Health and Human Services.

Contributors

M.E. Reller, Y.J.M. Mong, and R.E. Quick designed the study, analyzed the data, and wrote the paper. R.M. Hoekstra supervised data analysis and contributed to the writing.

Acknowledgments

We thank Patricia Riley, Dr Luke Nkinsi, Reema Jossy, and Lori Buhi of the CARE–CDC Health Initiative for their support and Caran Wilbanks for her editorial assistance. We are grateful to Lysa Rasoanirina, Juvenal Eliasy, Charles Razafimandimby, and Blaise Todisoa for their good-natured, reliable assistance in the field. We are grateful to Georges Mamy Randrianaina, mayor of Fort-Dauphin, for logistical assistance and overall facilitation of this investigation. Above all, we thank Rabenjanoelina, assistant mayor of Fort-Dauphin, for his exceptional logistical, administrative, and field support.

References

1. Mates A, Shaffer M. Membrane filtration differentiation of *E. coli* from coliforms in the examination of water. *J Appl Bacteriol.* 1989;67:343–346.

2. Han AM, Oo KN, Midorikawa Y, et al: Contamination of drinking water during collection and storage. *Trop Geogr Med.* 1989;41:138–140.

3. Swerdlow DL, Malenga G, Begkoyian G, et al. Epidemic cholera among refugees in Malawi, Africa: treat-

ment and transmission. *Epidemiol Infect.* 1997;118: 207–214.

4. Hammad ZH, Dirar HA. Microbiological examination of sebeel water. *Appl Environ Microbiol.* 1982;43: 1238–1243.

5. Quick RE, Venczel LV, Mintz ED, et al. Diarrhoea prevention in Bolivia through point-of-use water treatment and safe storage: a promising new strategy. *Epidemiol Infect.* 1999;122:83–90.

6. Mintz ED, Tauxe RV, Levine MM. The global resurgence of cholera. In: Noah N, O'Mahony M, eds. *Communicable Disease Epidemiology and Control.* Chichester, England: John Wiley & Sons Ltd; 1998: 63–104.

7. Mintz ED, Bartram J, Lochery P, Wegelin M. Not just a drop in the bucket: expanding access to point-of-use water treatment systems. *Am J Public Health.* 2001; 91:1565–1570.

Seeking Safe Storage: A Comparison of Drinking Water Quality in Clay and Plastic Vessels

Paul Ogutu, Valerie Garrett, MD, Peter Barasa, Sam Ombeki, Alex Mwaki, and Robert E. Quick, MD, MPH

Several point-of-use water treatment interventions have shown the beneficial health effect of drinking water treated and stored in narrow-mouthed, spigoted plastic vessels designed to reduce chlorine decay and limit recontamination.[1,2] However, more than 90% of the 43 000 households targeted by the Nyanza Healthy Water Project in western Kenya, Africa, preferred traditional, wide-mouthed clay vessels.[3] In laboratory- and village-based evaluations, we compared chlorine decay and disinfection rates in turbid surface water treated and stored in locally available clay vessels and plastic jerry cans.

We evaluated 3 vessel types: (1) wide-mouthed, 20-L clay vessels; (2) narrow-mouthed, 20-L clay vessels with lids and spigots (modified clay vessel); and (3) narrow-mouthed, 20-L plastic jerry cans with lids (Figure 1). We treated water with 1% sodium hypochlorite and measured free chlorine levels with colorimetric comparators. We assessed the microbiological quality of treated and untreated water with the membrane filtration technique and culture media selective for *Escherichia coli*.[4]

In the laboratory evaluation, we determined that the chlorine dose necessary to achieve a free chlorine level greater than 0.20 mg/L for 24 hours or longer was 16 mL. We then treated 20-L water samples in each vessel with 16 mL of 1% sodium hypochlorite (8 mg/L); measured free chlorine levels after 0.5, 4, 8, 12, and 24 hours; and cultured water after 0.5 and 24 hours.

In the village evaluation, 10 of 20 volunteer households were randomly selected to receive new, modified clay vessels. The remaining 10 used their own freshly cleaned traditional clay vessels. Within each group, 5 households also were selected to receive plastic jerry cans. We then filled each vessel with 20 L of river water, treated it with 16 mL of 1% sodium hypochlorite (8 mg/L), and measured free chlorine levels and cultured water after 0.5 and 24 hours.

In the laboratory evaluation, untreated river water had a baseline *E coli* count of 100 colony-forming units (CFUs) per 100 mL. After treatment, the free chlorine decay rate was 4% per hour in the plastic jerry can, 8% per hour in the modified clay vessel, and 9% per hour in the traditional clay vessel (Figure 2). After 24 hours, the free chlorine level was highest in the jerry can; however, all vessels had a free chlorine level greater than 0.2 mg/L. *E coli* (range = 5–21 CFU/100 mL) was recovered from

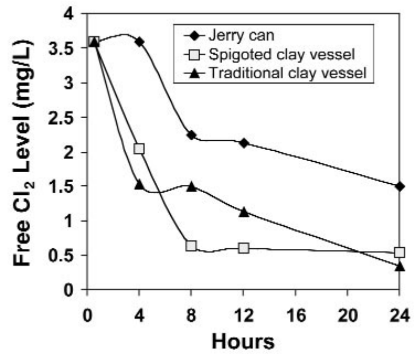

FIGURE 2—Free chlorine (Cl_2) levels in river water treated with 16 mL (8 mg/L) of 1% sodium hypochlorite solution, by time interval: Laboratory study, Ariri, Kenya, May 2000.

FIGURE 1—Vessels used in laboratory and village evaluations in western Kenya.