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Cholera Outbreak in Kenyan Refugee Camp: Risk Factors for Illness and Importance of Sanitation

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Abstract. An outbreak of watery diarrhea struck within the Kakuma refugee camp in Kenya in April 2005; 418 people were treated, and 4 persons died. *Vibrio cholerae* O1 was isolated from 33 patients. In June 2005, we conducted a retrospective matched case-control study to define risk factors associated with cholera among camp residents and identify interventions that could prevent further cases and future outbreaks. We identified cases of cholera through medical records at the main health facility in the camp and matched controls (without watery diarrhea since November 2004) to the cases by age category (< 2, 2–4, 5–14, and > 14 years) and location of residence within the camp. Cases were defined as any person of any age with profuse, effortless watery diarrhea (three or more stools in 24 hours). A multivariate model showed that storing drinking water at home in sealed or covered containers was protective against cholera (matched odds ratio [MOR] = 0.49 [0.25, 0.96]), whereas "sharing a latrine with at least three households" (MOR = 2.17 [1.01, 4.68]) and arriving at the Kakuma camp on or after November 2004 (MOR = 4.66 [1.35, 16.05]) were risk factors. Improving sanitation and promoting methods to ensure safe drinking water are likely to be effective measures in moderating future cholera outbreaks in this setting. Higher risks for cholera illness among refugees recently "in-migrated" suggest that there may be value in targeting new arrivals in the camp for risk reduction messages and interventions, such as covered water storage containers, to prevent cholera.

INTRODUCTION

Refugee camps are exceptionally vulnerable to cholera because of constrained resources, poor sanitation infrastructure, overcrowding, transitory populations, and poor nutritional status of inhabitants. Within 2005–2006, for instance, cholera outbreaks were reported from refugee settings including Thailand (370 cases), Ghana (2 fatalities), Congo DR (165 cases; 4 fatalities), Uganda (25 cases; 2 fatalities), and Pakistan (25 fatalities).[1–5] These outbreaks have all been caused by the El Tor biotype, endemic in sub-Saharan Africa since 1970.[6]

In 2005, cholera struck a number of communities in Kenya.[7] During this period, the Kakuma refugee camp, located in northwestern Kenya, was also affected. A team from the Kenyan Ministry of Health, along with the Field Epidemiology and Laboratory Training Program,[8] and the Centers for Disease Control and Prevention's (CDC) International Emerging Infections Program, was dispatched to Kakuma on June 15, 2005 to conduct an epidemiologic study.

Kakuma refugee camp, located ~130 km from the Southern Sudanese border, was established in 1991 to serve primarily as a refuge for Sudanese fleeing civil war. In July 2004, the camp had an official population of just over 90,000 refugee-residents, primarily from Sudan (77%), but with considerable representation from Somalia (19%). Kakuma is broadly organized according to four areas, Kakuma 1 through Kakuma 4. Kakuma 1 is the largest of these areas and is further subdivided by ~80 subareas (Figure 1). The International Rescue Committee (IRC) provides health and sanitation services within the camp, under the coordination of the Ministry of Health and United Nations High Commission for Refugees UNHCR. IRC operates one large hospital offering services free of charge to refugees and runs additional clinics located throughout the camp. Dwellings within the camp are semi-permanent and are primarily composed of mud and earthen brick.

Water is provided throughout the camp through seven boreholes distributing 1.7 million liters of water per day, equating to 18.9 liters/person/day, which is slightly less than the UNHCR recommendation of 20 liters/person/day. This water is chlorinated in steel reservoirs before distribution. Nonetheless, because of water leakage within the distribution system, uneven population distribution, and a higher population than is officially recorded, actual water use is estimated to range between 8 and 17 liters/person/day. Furthermore, the chlorination process leads to large fluctuations in residual chlorine levels at water taps, testing between 0 and 5 mg/liter (UNHCR recommends 0.5 mg/liter).[9]

Officially, camp latrine coverage is one latrine per 13 refugees, up from a user ratio of 1:49 in 2001.[10] However, this is an average for the entire camp and does not address wide fluctuations depending on density of areas within the camp.

To identify risk factors associated with cholera illness during this outbreak, we conducted a case-control study. Better understanding of risk factors specific to the Kakuma outbreak may help the camp's public health service providers develop evidence-based intervention and prevention measures specific to the dynamics of the Kakuma camp, and may provide information relevant to prevention of cholera in similar settings.

MATERIALS AND METHODS

Descriptive epidemiology. We reviewed and abstracted records from the IRC hospital and clinics to identify cases of watery diarrhea from April through June 2005; we collected demographic information to characterize the descriptive epidemiology. A case was defined as any person suffering from watery diarrhea (at least three stools in a 24-hour period) who was admitted to the IRC cholera ward from April 1 through June 30, 2005; all patients in IRC's cholera ward had

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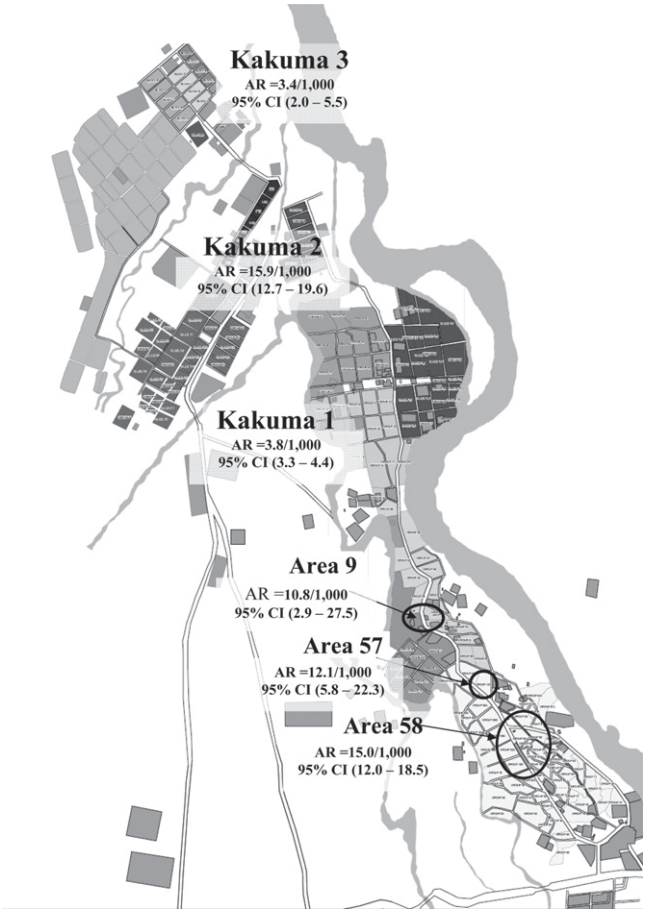

FIGURE 1. Map of Kakuma Refugee Camp. Source: Adapted from map provided by International Rescue Committee.

experienced at least three stools in a 24-hour period. This case definition was adapted for greater sensitivity in an outbreak setting from the World Health Organization (WHO) case definition that excludes persons younger than 5 years of age.

Case-control study. To determine risk factors associated with cholera illness, we conducted a retrospective matched case-control study of refugees, defined as those living within the Kakuma refugee camp.

Case finding was done through IRC's database of cholera cases derived from inpatient information provided by patients evaluated at the camp's hospital. These records captured the name, sex, age, date of admission, and general location of residence within the camp for all cases. Because it was difficult to find any particular case after release from the IRC hospital, the investigation team worked with IRC's community health workers to identify cases for inclusion in the study. Two controls were matched to each case by location of residence within the camp and age. Controls were age-matched on the following four age categories: < 2, 2–4, 5–14, and > 14 years. Controls were found for each case by a member of the investigation team standing in front of the case's house and spinning a pin or bottle to determine a starting direction. Next, a number between two and five was drawn at random to indicate the number of houses in the chosen direction to proceed before attempting to interview the first control.

Individuals were excluded from being controls if they reported suffering from watery diarrhea since November 2004. Potential controls of the same age category as the case, if available and eligible, were interviewed. If no suitable control existed at the chosen house, the investigation team moved to the right of the house and continued moving to the right until an appropriate control was found. This process was repeated from the case's house to find the second control.

Standardized questionnaires, written in English, were administered to cases and controls in their native tongue by bilingual/multi-lingual trained interviewers recruited from the refugee community. These questionnaires collected basic demographic information and contained questions pertaining to potential food and water exposures and hygiene practices from November 2004 to the interview date. Furthermore, data were also collected on date of arrival to the camp with refugees arriving on or after November 2004 considered to be recent arrivals. In cases where a child was the study subject, questions were asked to another adult within the household (typically a family member) who had knowledge of the child's activities.

Primary microbiologic assessment of stool was done at the IRC laboratory at the Kakuma refugee camp and at the CDC/KEMRI laboratory in Kisian, near Kisumu. Stool was either directly plated on thiosulfate-citrate-bile salts agar (TCBS) or transported on Cary-Blair transport media and plated on TCBS agar. Colonies of growth were evaluated using standard biochemical reactions, and *Vibrio cholerae*–positive isolates were serogrouped and serotyped using agglutination tests with commercial anti-sera.[11]

Data were entered into Epi Info software version 3.3. Data were transferred to an SAS database, version 8.0 (SAS Institute, Cary, NC) for data cleaning and analysis.

Odds ratios (ORs) for univariate analysis were calculated, and the Mantel-Haenzel method was used for categorical variables and maximum likelihood estimation for continuous variables. Although controls were individually matched to two cases during the study, matched sets were pooled across the matching criteria for analysis, thus creating 34 matched groups from 22 regions and 4 age categories (many regions had only cases who were > 14 years old). This method of pooling was conducted to reduce the number of parameters in the model and therefore increase precision.

Analysis of the multivariate model was conducted using conditional logistic regression by SAS software (version 9.1; SAS Institute). The univariate analysis served as a screening phase for variables to be included in a multivariate model; all exposure variables were included in the initial multivariate model if their associated P value under univariate analysis was ≤ 0.1. A backward elimination procedure was used where variables that were least significant were systematically dropped from the model until only variables with $P \leq 0.05$ remained in the model. The model also assessed for all two-way interactions between exposure variables included in the initial model; none were found to be significant at the 95% confidence level. Finally, collinearity was assessed with an SAS macro based on diagnostics using the information matrix[12]; no collinearity was found.

RESULTS

Descriptive epidemiology. During February 2005, there was an increase in watery diarrhea incidence within the Kakuma camp including 28 cases of clinically diagnosed cholera and

one patient with *V. cholerae* serogroup O1 isolated from stool. After February, however, there were no new cases identified until the disease re-emerged in April 2005. From April until the end of June, there were 522 cases of watery diarrhea (Figure 2). 418 (80.0%) of which were admitted to the IRC hospital, including 33 patients with *V. cholerae* O1, serotype Inaba isolated from stool (records on the number of stool cultures processed were unavailable); 4 patients died. No other pathogens were isolated. Of these IRC hospital cases, 348 (83.3%) were from the camp's refugee population, whereas the other 70 (16.7%) were from the Kenyan host community. Most cases occurred between mid-May to mid-June. IRC interventions included enhanced community health education, establishment of an isolated cholera ward, and active case finding.

Although cholera cases occurred throughout the camp (overall camp attack rate of 4.9 cases/1,000 inhabitants), cases clustered in specific areas. For the entire period of April through June, 2005, Kakuma 2 experienced the highest attack rate (15.9 cases/1,000 inhabitants), followed by areas 58 (15.0/1,000) and 57 (12.1/1,000) of Kakuma 1 (Figure 1).

Case-control study. Ninety (25.9%) of the 348 cases in camp residents were located and enrolled along with 170 matched controls. Cases and controls were similar in sex, distribution by age category, and nationality (Table 1). Cases were distributed throughout the refugee camp (Table 2).

Being a recent arrival was the only risk factor found to be significantly associated with cholera in univariate analysis (matched OR [MOR] = 3.66 [1.16, 11.53]). Storing water in the home in sealed or covered containers tended to be protective (MOR = 0.55 [0.29, 1.03]). Other variables included in the multivariable analysis were using soap during hand washing and sharing a latrine with three or more households (Table 3).

In multivariate analysis, keeping water stored in home sealed/covered was protective (MOR = 0.49 [0.25, 0.96]), whereas sharing a latrine with three or more households (MOR = 2.17 [1.01, 4.68]) and being a recent arrival in the camp (MOR = 4.66 [1.35, 16.05]) were associated with increased risk for disease (Table 4).

DISCUSSION

Refugee camps typically have a number of characteristics making them vulnerable to cholera such as poor sanitation, inadequate food storage, and inconsistent availability of adequate quantities of safe water.[13] In addition, refugees may have compromised nutritional status and have migrated from conflict areas where there are exposures to cholera. These characteristics, especially limited water supply, were applicable to the Kakuma camp at the time of the outbreak.[9] Limited water supply not only impacts health directly but is an obstacle to the implementation of countermeasures focused on improved hygiene and sanitation.

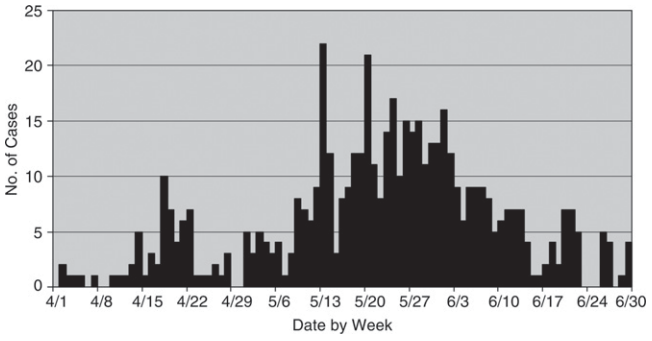

FIGURE 2. Epidemiological curve for cholera cases in Kakuma outbreak (April 1 through June 30, 2005; $N = 522$).

TABLE 1
Demographic characteristics of study subjects

Characteristic	Cases [*n*/(%)] ($N = 90$)	Controls [*n*/(%)] ($N = 170$)
Sex*		
Male	41/(46%)	69/(41%)
Age category (years)		
< 2	5/(6%)	8/(5%)
2–4	7/(8%)	10/(6%)
5–14	17/(19%)	29/(17%)
> 14	61/(68%)	123/(72%)
Nationality		
Sudanese	72/(80%)	140/(82%)
Somali	17/(19%)	27/(16%)
Other	1/(1%)	1/(0.5%)

*Sex information missing for four controls and one case.

Refugees arriving to the Kakuma camp during or after November 2004 were found to be at significantly greater risk for cholera illness. November 2004 was the date chosen for analysis because IRC officials reported that a series of cases of cholera had occurred at that time as well; cases were included in the study with arrival dates from every year from 1992 through 2005. Twenty-seven of these cases had arrival dates in 2004 or 2005, whereas there were only two cases per year with arrival dates in 1995 and 1996. All refugees within the camp were reported to receive the same benefits, regardless of how long they have lived in the camp. The study matched on location, to control for geographic factors such as infrastructure and sanitation. We found no other published studies (refugee camp or otherwise) where recent in-migration was a significant risk factor. One possible explanation is that cholera had occurred in the camp before November 2004, resulting in immunity to cholera for many of the refugees. Therefore, newer refugees with no exposure history would be vulnerable to cholera illness when entering a population where cholera was spreading. An alternative hypothesis would be that new arrivals to the camp were placed in areas where the majority of cases were clustering, making those new arrivals more vulnerable. Whereas Kakuma 2 and area 58 of Kakuma 1 are not in close proximity to one another (Figure 2), they are culturally similar because both areas are predominated by Sudanese Dinka from southern Sudan. Most new arrivals from Sudan were located in Kakuma 2. Again, because the study matched on location, this effect should have been controlled for. Additionally, there may be some unmeasured risk factor associated with newer arrivals making them more vulnerable to illness after infection. One such possibility is that new arrivals may follow practices that facilitate transmission of enteric pathogens, including failure to protect water containers from contamination by family members, shown to be a key risk factor for cholera in studies from India.[14] Finally, although arrival date is strongly associated with illness, only 13% of cases were found to have this exposure. However, this low proportion could be attributable to better proficiency at locating cases with more permanent residences versus those who arrived more recently.

TABLE 2
Cholera cases, enrolled cases, and attack rates for most heavily affected camp areas

Camp location		Cases	Study cases	Study percent of cases	Population	Attack rate per 1,000
Kakuma 1	6	4	3	75.0%	857	4.7
	9	4	3	75.0%	371	10.8
	10	29	8	27.6%	3,821	7.6
	17	6	2	33.3%	2,140	2.8
	21	6	1	16.7%	780	7.7
	31	5	3	60.0%	878	5.7
	32	4	0	0.0%	1,683	2.4
	56	4	0	0.0%	824	4.9
	57	10	1	10.0%	825	12.1
	58	87	23	26.4%	5,791	15.0
	71	6	4	66.7%	1,189	5.0
	78	10	0	0.0%	3,109	3.2
	Other*	NA	14			NA
Kakuma 2		87	24	27.6%	5,488	15.9
Kakuma 3		17	4	23.5%	4,929	3.4

* Fourteen study cases sparsely distributed throughout less affected areas of Kakuma 1.
NA = not applicable.

Severe cholera is far less common than a mild or asymptomatic infection. For every one case of severe cholera, there are likely 30–100 mild or asymptomatic cases[15]; a fairly high infectious dose (10^8 bacteria) is needed to cause severe illness in most otherwise healthy people.[6] Many refugees come from rural and war-torn areas with few resources and may therefore have weakened immune systems caused by malnutrition or other infections. Although malnutrition does not put people at increased risk for contracting cholera, it is possible that conditions that weaken immune systems would make it more likely that infection would result in symptomatic illness, as has recently been shown in Mozambique to be the case for HIV infection.[16] Although we cannot define the basis for the association of cholera illness in this outbreak with the date of arrival to the camp, prevention efforts should recognize the vulnerable nature of new arrivals and provide this group additional help including educational interventions, safe water storage containers, chlorination tablets for point-of-use treatment, soap,[17] and active surveillance. Cholera vaccination seems to be particularly useful in high-risk circumstances[18–21] and may have helped to control the outbreak, especially if vaccination programs targeted new arrivals to the camp.

Inspection of camp areas where cholera cases were clustered often showed a lack of latrines. Sharing a latrine with three or more households was found to be a significant risk factor in multivariate analysis. Furthermore, without active participation from the community, latrines are not as likely to be completed or maintained. Such latrine maintenance is further complicated by groups within the camp that do not place value on latrine use, such as refugees from southern Sudan who preferred to use the bush. Situations where multiple households use the same latrine provide additional opportunities for fecal–oral transmission of cholera throughout the community. Shigella transmission has been shown to be heightened through similar circumstances.[22] Possible measures for improving latrine use include a better accounting mechanism for functioning latrines and health promotion campaigns focusing on the importance of using a latrine.

Keeping water stored in the home in sealed or covered containers was found to be protective against cholera. This finding is consistent with study results from a 1993 cholera outbreak study in Malawi,[23] during which refugees were contaminating water collected at taps and in their homes with fecal coliforms. Introduction of a bucket with a lid reduced the incidence of diarrhea in children younger than 5 years old in the camp by 31%.[24] A United Nations water engineering study at the Kakuma camp carried out during the cholera outbreak found that, although water collected at the camp's communal taps was infected with fecal coliforms, water sampled from homes within the camp had a much higher degree of contamination.[9] The use of community health workers to promote safe storage of water within the home could be an inexpensive and effective way to reduce cholera incidence, provided that good covered or sealed containers are available to camp residents. Since May 2005, IRC instituted a number a countermeasures to combat the outbreak including an educational campaign

TABLE 3
Univariate analysis for select potential risk factors for acute cholera illness

Risk factor	Cases ($N = 90$)	Controls ($N = 170$)	Matched OR (95% CI)	P value
Drinking river water	24/29 (83)	38/51 (75)	1.6 (0.4, 5.8)	0.48
Storing water in jerry can	87/89 (98)	157/166 (95)	2.8 (0.6, 14.4)	0.22
Usually keep water stored in house	78/90 (87)	135/169 (80)	1.8 (0.8, 3.8)	0.15
Keep water stored in house covered*	45/76 (59)	94/127 (74)	0.6 (0.3, 1.0)	0.06
Reheats food cooked previous day	13/29 (45)	25/56 (45)	1.6 (0.4, 5.8)	0.49
Washes hands before eating	86/88 (98)	163/166 (98)	1.7 (0.2, 16.7)	0.66
Washes hands after eating	80/86 (93)	143/160 (89)	2.2 (0.8, 6.5)	0.14
Washes hands after visiting toilet	71/90 (79)	143/178 (84)	0.7 (0.4, 1.4)	0.35
Washes hands with soap*	68/87 (72)	132/162 (81)	0.6 (0.3, 1.1)	0.09
Uses Latrine	54/89 (61)	114/169 (67)	0.9 (0.5, 1.6)	0.77
Fifteen or more people sharing the same latrine	31/52 (60)	54/112 (48)	1.5 (0.7, 3.3)	0.33
Three or more households sharing same latrine*	34/51 (67)	57/111 (51)	1.9 (0.9, 4.4)	0.11
Arrived in camp on/after November 2004*	11/87 (13)	6/166 (4)	3.7 (1.2, 11.5)	0.03

* $P \leq 0.1$.

TABLE 4
Matched ORs from multivariate analysis

Variable	Matched OR	95% CI
Water stored in house sealed/ covered	0.49	0.25–0.96
Three or more households sharing same latrine	2.17	1.01–4.68
Arrived at camp on or after November 2004	4.66	1.35–16.05

about the importance of hand washing, food handling and water treatment with chlorine tablets. Effectiveness of these countermeasures is highly dependent on continued vigilance in providing access to chlorine tablets, soap, and safe water storage containers.

A methodological limitation of our study was the time lag between the onset of many of the case's illnesses and the execution of this study. Asking cases and matched controls about exposures in the week before the case's illness would have introduced considerable recall bias, producing exaggerated estimates of risk factors. Because the study of the outbreak spanned a long period of time, recall bias would be of particular concern, especially for controls that did not have illness as a point of reference. Therefore, the study was designed to ask subjects about typical exposures since November 2004 and to measure the frequency or degree of those exposures. The downside of this was that many individuals might have changed their practices because of IRC's educational interventions since the beginning of the outbreak, and therefore their exposure status might have been misclassified. Such behavioral changes, if adopted by both cases and controls in equivalent proportions, would bias estimates toward the null.

Another source of concern in this study is misclassification of disease status. The El Tor biotype of *V. cholerae* O1, currently circulating in sub-Saharan Africa, has been observed to have a symptomatic to asymptomatic ratio ranging from 1:30 to 1:100[15]; therefore, many of the asymptomatic controls included in the study may have been infected with cholera during the investigation period. In addition, because microbiologic testing was limited to a fraction of the total number of patients, most cases were identified through fairly non-specific case definitions; thus, it is likely that some of the patients with watery diarrhea (especially those < 5 years of age) were misclassified as having cholera. These problems would tend to dilute the observed effect of risk factors for infection with *V. cholerae*. As such, risk factors found to be significantly associated with cholera may better be interpreted as risk factors for clinically significant cholera versus asymptomatic or mild infections.

No single source of cholera was identified during this study, and the epidemiologic curve is not characteristic of a point-source outbreak. Before the study began, the riverbed located adjacent to the camp was hypothesized to be a likely source of sickness.[9] The reasoning was related to a cultural practice of defecating on the banks near the riverbed by many of the refugees. It was thought that *V. cholerae* O1 organisms in feces were washed into the riverbed during rains. Later, refugees would dig shallow wells in the riverbed to harvest potentially contaminated water. This study, however, indicates that cases were not more likely than controls to use water from this source and therefore provides no evidence to suggest that the outbreak was associated with riverbed water or that this water source was contaminated with *V. cholerae* O1. Other water sources (communal taps, wells, from vendors, rain water, bottled) were also found not to be significantly associated with illness in univariate or multivariate analysis. There seemed to be a number of factors impacting the outbreak, including hygiene and stored water quality. Such multiplicity in risk factors is not uncommon in cholera outbreaks, although some outbreaks have been clearly associated with water sources or contaminated foods.[25–32]

This outbreak was one of five cholera outbreaks that occurred in Kenya in 2005 and resulted in nearly 1,000 reported cases in geographically discrete locations > 1,000 km apart.[7] PFGE patterns of isolates from each of the outbreaks (including the Kakuma outbreak) were similar,[7] suggesting, along with the temporal clustering, that the outbreaks may have been linked. There is substantial mobility between Kakuma and southern Sudan (where another cholera outbreak was identified with an isolate with a similar pulsed-field gel electrophoresis (PFGE) pattern[7]) and from Kakuma to other parts of Kenya, especially Nairobi. Given easy transportation connections that exist in east Africa, the refugee setting may have been a reservoir and focus for rapid transmission to other areas.

Consistent with findings from this study, refugee camps have a number of characteristics that make cholera prevention and control challenging, including limitations in personal hygiene and lack of sanitary food storage and adequate water infrastructure, as well as poor nutritional status of refugees. There are also inherent social problems, because refugees are usually transient and from resource-poor and war-torn regions. Efforts to improve sanitary practices and to enhance drinking water availability and safe storage practices in and around the camp are likely to be effective measures in both preventing and moderating future cholera as well as other diarrheal outbreaks. A strong active surveillance system, especially for recent arrivals, could help detect reintroduction of the disease into the camp early enough to lead to effective responses to moderate transmission. When the surveillance system does detect cholera, a timely and well-coordinated intervention plan should be implemented based on findings from this study and others like it.

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