Am. J. Trop. Med. Hyg., 68(6), 2003, pp. 671–677

EPIDEMIOLOGY OF SPORADIC BLOODY DIARRHEA IN RURAL WESTERN KENYA

JOHN T. BROOKS, ROGER L. SHAPIRO, LATA KUMAR, JOY G. WELLS, PENELOPE A. PHILLIPS-HOWARD, YA-PING SHI, JOHN M. VULULE, ROBERT M. HOEKSTRA, ERIC MINTZ, AND LAURENCE SLUTSKER

Foodborne and Diarrheal Diseases Branch, and Biostatistics and Information Management Branch, Division of Bacterial and Mycotic Diseases, National Center for Infectious Diseases; Epidemic Intelligence Service, Epidemiology Program Office; and Division of Parasitic Diseases, National Center for Infectious Diseases, Centers for Disease Control and Prevention, Atlanta, Georgia; Center for Vector Biology Control and Research, Kenya Medical Research Institute, Kisumu, Kenya

Abstract. We conducted laboratory-based surveillance and a case-control study to characterize the epidemiology of bloody diarrhea in rural Western Kenya. From May 1997 through April 2001, we collected stool from 451 persons with bloody diarrhea presenting to four rural clinics. Cultures of 231 (51%) specimens yielded 247 bacterial pathogens: 198 *Shigella* (97 *S. flexneri,* 41 *S. dysenteriae* type 1, 39 *S. dysenteriae* type non-1, 13 *S. boydii*, 8 *S. sonnei*), 33 *Campylobacter*, 15 non-typhoidal *Salmonella*, and 1 *Vibrio cholerae* O1. More than 90% of the isolates (excluding *Campylobacter*) were resistant to trimethoprim-sulfamethoxazole and tetracycline, and more than 80% were resistant to ampicillin. Most (74%) ill persons received medication to which their isolate was resistant. Drinking Lake Victoria water and sharing latrines between multiple households increased risk of bloody diarrhea. Washing hands after defecating was protective. Providing safe drinking water and more latrines, and promoting hand washing could reduce the burden of illness from bloody diarrhea while limiting injudicious antimicrobial use.

INTRODUCTION

Diarrhea causes substantial illness among rural sub-Saharan Africans;[1] visibly bloody diarrhea causes proportionally greater morbidity and mortality.[2,3] Antibiotics are recommended for treating bloody diarrhea to shorten the duration of illness, decrease morbidity and mortality, and reduce the duration of bacterial shedding.[4–6] Antimicrobial resistance among the major bacterial causes of bloody diarrhea is increasing worldwide.[7] In sub-Saharan Africa, repeated prolonged outbreaks of dysentery with high case fatality rates have increased the demand for antibiotics; causative pathogens such as *Shigella dysenteriae* type 1 have developed resistance to locally affordable and available antibiotics.[8] Treatment of dysentery with antibiotics to which the etiologic agent is resistant may prolong illness and increase risk of hemolytic uremic syndrome and death.[9,10]

Following an outbreak of dysentery caused by *S. dysenteriae* type 1 near Kisumu in rural western Kenya during the mid-1990s[11] we established surveillance for diarrheal disease in this area. The project was conducted collaboratively between the Kenya Medical Research Institute (KEMRI) and the U.S. Centers for Disease Control and Prevention (CDC). The results of the first year of general surveillance for bacterial diarrhea have been previously reported.[12] We report the results of four years of laboratory-based surveillance for bloody diarrhea and the findings of a case-control study to identify preventable risks.

MATERIALS AND METHODS

Study site. The study took place in the Asembo Bay area of Siaya District in Nyanza Province in western Kenya (Figure 1), a rural community bordering Lake Victoria populated by the Luo ethnic group. Fishing, raising cattle, and subsistence farming are the principal occupations. Villages are organized as loose conglomerates of family compounds separated by garden plots, grazing land, and streams. Rainfall is seasonal, occurring generally from March to May and from October to December. Nyanza is one of Kenya's most impoverished provinces; an estimated 63% of the population lived in poverty in 1997.[13] This province also has one of the nation's lowest immunization rates, highest infant mortality,[13] and highest prevalence of human immunodeficiency virus (HIV) (22% among adults 15–49 years old in 2000).[14] Malnutrition is common; endemic diseases include malaria, tuberculosis, and schistosomiasis.

Surveillance and specimen collection. Between May 1, 1997 and September 30, 2001 we conducted laboratory-based surveillance for diarrheal illness at three rural clinics: two government health clinics and the outpatient clinic of a mission hospital. Surveillance was conducted in conjunction with a study of the impact of insecticide-treated bed nets on child mortality and morbidity. On September 1, 1997 a fourth surveillance site was added at a private clinic. All four clinics treated adults and children. Surveillance was suspended during the last two weeks of each year for annual holidays and from October 1999 through January 2000 due to technical problems. At each clinic we enrolled up to five persons with diarrhea daily, defined as three or more bowel movements in any 24-hour period within the preceding five days. We defined diarrhea as bloody if blood was visible in the specimen or if the patient (or their caretaker) reported seeing blood in their stool. After each participant provided written informed consent, we collected demographic information, symptoms, and medication taken before the visit and prescribed as a result of the visit. We also collected stool specimens during the visit, which were placed immediately in Cary-Blair transport medium and kept cooled for same-day transport to the KEMRI/CDC Microbiology Laboratory (Figure 1). Specimens arrived at the laboratory within six hours of collection and were processed the same day. We returned the results of bacterial cultures and antimicrobial susceptibility testing to clinic staff at each surveillance site; these results were used to guide therapy.

Laboratory procedures. All stool specimens were cultured for *Shigella*, *Salmonella*, *Vibrio*, and *Campylobacter*; media, reagents, bacterial isolation technique, and antimicrobial susceptibility testing were routinely quality-controlled. The first 100 specimens were cultured for *Escherichia coli* O157:H7

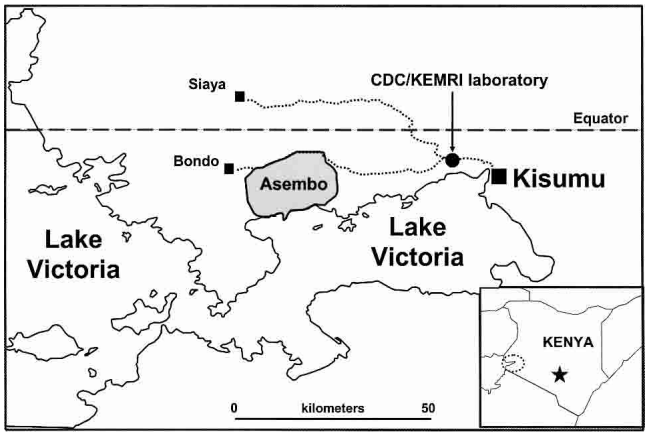

FIGURE 1. Location of Asembo research site in Kenya. CDC/KMRI = Centers for Disease Control and Prevention/Kenya Medical Research Institute.

using sorbitol MacConkey's agar and O157 latex reagent. We probed colony sweeps from a one-third random sample of cultures by a multiplex polymerase chain reaction (PCR) for gene sequences diagnostic for Shiga toxin-producing *E. coli* (STEC): Shiga toxins 1 and 2 (*stx*1, *stx*2),[15] and intimin (*eae*).[16]

We determined antimicrobial susceptibilities of all bacterial pathogens except *Campylobacter* to ampicillin, amoxicillin-clavulanate, ceftriaxone, chloramphenicol, ciprofloxacin, gentamicin, kanamycin, nalidixic acid, streptomycin, sulfisoxazole, tetracycline, and trimethoprim-sulfamethoxazole by the Kirby-Bauer disk diffusion method;[17] interpretive criteria for susceptibility testing of *Campylobacter* have not yet been established.

Case-control study. Between November 1, 1997 and September 30, 1999 we conducted a case-control study to determine risk factors for bloody diarrhea. We defined a case as any person enrolled in our surveillance study who reported bloody diarrhea. For each case, we endeavored to enroll two healthy controls matched by age group (< 1 year, 1–4 years, 5–10 years, 11–17 years, 18–65 years, and > 65 years) and sex within two weeks of each case's presentation to control for seasonal variation. We first approached persons with non-acute medical conditions (e.g., vaccination, birth control consultation) attending the same clinic where the case had presented. If within 10 days of enrolling a case we had enrolled no matching clinic-based controls we then sought healthy age group- and sex-matched controls from the case's village of residence. Starting at the case's home compound, we systematically solicited potential controls from neighboring compounds. We excluded as controls persons who reported any form of diarrhea or any other gastrointestinal symptoms within 14 days of enrollment. After obtaining written informed consent, local health workers administered an initial questionnaire to cases and controls in local dialect asking about drinking water sources and food eaten during the past seven days, and personal hygiene (e.g., use of latrines, hand washing). Within 14–30 days after enrollment, village health workers visited both cases and controls at home (repeat visits were made to compound-based controls) to conduct follow-up interviews and collect observational data about the household.

Statistical methods. Due to unanticipated difficulties locating controls, few were enrolled within the two-week time frame by which they were to be matched to their intended case. As a result, the matching element associated with time of illness was modified to common calendar year and month of interview. Cases and controls within each one-month interval were matched by age group, sex, and either the clinic where the case presented or the case's village of residence. Data were entered using Epi-Info version 6.04 (CDC, Atlanta GA).

For dichotomous variables, we calculated maximum likelihood estimates of matched odds ratios (MOR) and their 95% confidence intervals (95% CIs) by conditional logistic regression analysis using SAS 8 (SAS Institute Inc., Cary, NC); MORs with P values ≤ 0.05 were considered significant. For continuous variables, we compared means by Student's t-test and medians by the Wilcoxon rank sum method; differences that produced two-tailed P values ≤ 0.05 were considered significant. We constructed a multivariable model using a step wise selection strategy that incorporated significant and nearly significant ($P > 0.05$ and $P < 0.10$) associations and evaluated for covariances and interactions. We calculated the fraction of illnesses attributable to or prevented by exposures that were significant in multivariable analysis by using MORs as estimates for relative risk on the assumption that the point prevalence of bloody diarrhea in the population studied was < 5%.

Scientific ethics. The CDC Institutional Review Board and the KEMRI Ethical Review Committee reviewed and approved the protocols for both the surveillance project and the case-control study. Informed consent was obtained from all patients, or their parents or guardians. Human experimentation guidelines of the U.S. Department of Health and Human Services and the Kenya Medical Research Institute were followed.

RESULTS

Surveillance. During 48 months of surveillance 2,374 specimens were collected, of which 451 (19%) were from persons with bloody diarrhea. The median number of specimens collected daily from all sites was three and never exceeded the potential maximum of five specimens per site per day. The median age of persons with bloody diarrhea was 26 years (interquartile range [IQR] = 15–39 years) and 50% were male. Patients presented for evaluation and were interviewed a median of two days after illness onset (IQR = 1–4 days). Reported symptoms included abdominal cramping (78%), fever (76%), nausea (53%), vomiting (31%), coincident mucousy diarrhea (82%), and coincident watery diarrhea (56%). We isolated no bacterial pathogen from 211 (49%) specimens, at least one pathogen from 231 (51%) specimens, and more than one pathogen from 16 (4%) (Table 1). *Shigella* was most common and accounted for 198 isolates (44% of all specimens): 97 (22%) *S. flexneri*, 41 (9%) *S. dysenteriae* type 1, 39 (9%) other *S. dysenteriae*, 13 (3%) *S. boydii*, and 8 (2%) *S. sonnei*. *Campylobacter* (33 isolates, 7%), nontyphoidal *Salmonella* (15 isolates, 2%), and a single *Vibrio cholerae* O1 (< 1%) were also isolated. No *E. coli* O157:H7 was isolated from the first 100 specimens from persons with bloody diarrhea, and there was no evidence of STEC among 165 (36%) randomly selected specimens screened by the multiplex PCR.

TABLE 1

Bacterial enteric pathogens isolated from 451 persons with bloody diarrhea in Asembo, western Kenya, May 1, 1997 to April 30, 2001

	All specimens (%)* (n = 451)	Specimens from case-patients in case-control study (%) (n = 97)
No growth	8 (2)	3 (3)
Normal growth	212 (47)	42 (43)
Yielded an enteric pathogen	231 (51)	52 (54)
Total pathogens isolated	247	54
Shigella, all	**198 (44)**	**46 (47)**
S. flexneri	97 (22)	17 (18)
S. dysenteriae, type 1	41 (9)	11 (11)
S. dysenteriae, other	39 (9)	12 (12)
S. boydii	13 (3)	4 (4)
S. sonnei	8 (2)	2 (2)
Campylobacter	**33 (7)**	**6 (6)**
C. jejuni	21 (5)	3 (2)
C. coli	6 (1)	1 (1)
C. jejuni/coli	1 (<1)	–
Non-*jejuni,* non-*coli Campylobacter*	5 (<1)	2 (2)
Salmonella, non-typhoidal	**15† (3)**	**2 (2)**
Group B	6 (1)	–
Group C1	–	–
Group C2	4 (<1)	1 (1)
Group D	3 (<1)	1 (1)
Group E	2 (<1)	–
Vibrio cholerae serotype O1	**1 (<1)**	**–**

* Calculated as the percentage of isolates among all specimens rounded to the nearest 1%.
† 4 *S.* Typhimurium, 3 *S.* Enteritidis, 2 *S.* Heidelberg and *S.* Aberdeen, 1 each *S.* Chailey, *S.* Newport, *S.* Uganda, and *S.* Zanzibar.

Bloody diarrhea was most common among persons less than five years of age and young adults 20–29 years old (Figure 2). Among 77 specimens from children 0–4 years old that yielded 44 isolates, *Campylobacter* was isolated from 18 specimens (23%), and was the sole bacterial pathogen isolated from 13 specimens (17%). *Shigella* was isolated from 20 specimens in children 0–4 years old (26%), and was the sole isolate from 13 specimens (17%). In comparison, among 370 specimens from persons greater than or equal to five years old that yielded 201 isolates, *Campylobacter* was isolated from 15 specimens (4%), and was the sole isolate from nine specimens (2%). *Shigella* was isolated from 176 specimens in persons greater than or equal to five years old (48%), and was the sole pathogen from 169 specimens (46%). Age data were missing for four persons.

The antimicrobial susceptibilities of isolated pathogens are shown in Table 2. Excluding *Campylobacter*, < 10% of the isolates were susceptible to tetracycline, trimethoprim-sulfamethoxazole, sulfisoxazole, and streptomycin, 19% were susceptible to ampicillin, 33% to chloramphenicol, and 34% to amoxicillin-clavulanate. More than 95% remained susceptible to nalidixic acid, kanamycin, and gentamicin, and 100% to ciprofloxacin and ceftriaxone. As in many parts of sub-Saharan Africa, antibiotics were readily available without prescription in this community. The likelihood of isolating a pathogen did not differ significantly between persons who reported taking antibiotics for their diarrhea before stool col-

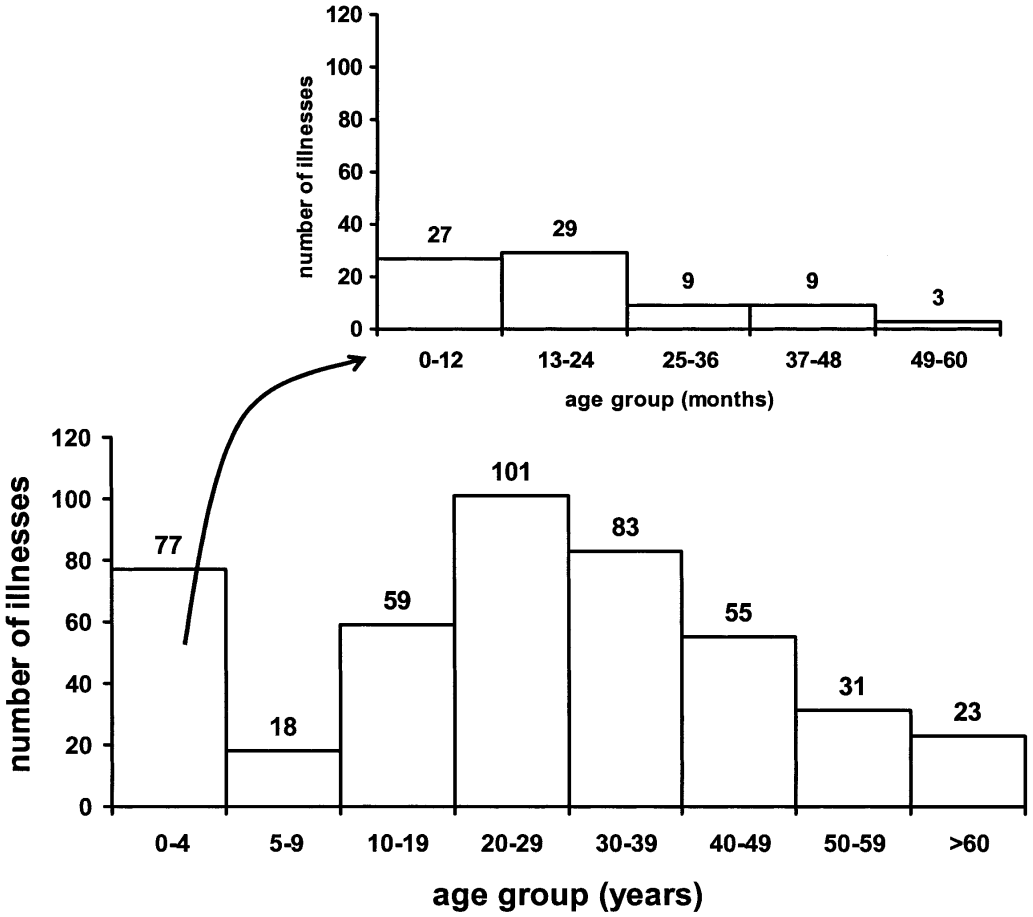

FIGURE 2. Cases of bloody diarrhea illness by age (n = 447) in western Kenya, May 1, 1997 to April 30, 2001. Age was missing for four subjects.

TABLE 2

Antimicrobial susceptibility patterns among 209 bacterial isolates tested from persons with bloody diarrhea in Asembo, western Kenya, May 1, 1997 to September 30, 2001*

Pathogen (number tested)	Percent susceptible isolates (percent moderately susceptible or intermediate if ≥1%)											
	Chl	TMP-SMZ	Tet	Cpfx	NA	Amp	SSZ	Stm	Km	Gm	Ctri	Amox-CA
All isolates† (209)	33	8 (1)	6 (1)	100	97	19	7 (2)	6	97 (1)	98	100	34 (23)
Shigella spp. (197)	30	5 (1)	2	100	98 (1)	17	7	4	98 (1)	99	100	32 (24)
S. dysenteriae type 1 (41)	0	7	0	100	100	2	7	7	100	100	100	22 (49)
S. dysenteriae (other (39)	74	0	5	100	97	13	10	0	97	97	100	56 (28)
S. flexneri‡ (96)	9	6 (2)	0	100	97 (1)	15	7 (1)	4	98 (1)	100	100	19 (14)
S. boydii (13)	100	8	8	100	100	46 (8)	0	0	100	100	100	62 (15)
S. sonnei (8)	100	0	12	100	100	88	0	0	100	100	100	88 (12)
Salmonella, nontyphoidal‡ (11)	82	64	64 (27)	100	82	54	9 (27)	54 (9)	73	73	100	54 (9)
Vibrio cholerae serotype O1 (1)	(100)	0	100	100	0	100	0	0	100	100	100	100

* Chl = chloramphenicol; TMP-SMZ = trimethoprim-sulfamethoxazole; Tet = tetracycline; Cpfx = ciprofloxacin; NA = nalidixic acid; Amp = ampicillin; SSZ = sulfasoxazole; Stm = streptomycin; Km = kanamycin; Gm = gentamicin; Ctri = ceftriaxone; Amox-CA = amoxicillin-clavulanic acid.
† Excludes *Campylobacter.*
‡ Susceptibility data available for 96 of 97 *S. flexneri* isolates and 11 of 15 *Salmonella* isolates.

lection compared not those who did not (54% and 50%, respectively; $P = 0.55$).

At the time of the clinic visit, 321 (71%) persons with bloody diarrhea were prescribed at least one antibiotic: 30% were prescribed amoxicillin, 20% trimethoprim-sulfamethoxazole, 11% doxycycline, and 10% tetracycline. Fewer than 10% were prescribed nalidixic acid, a fluoroquinolone, chloramphenicol, gentamicin, erythromycin, penicillin, or amoxicillin-clavulanate. Among 123 persons from whom a bacterial pathogen other than *Campylobacter* was isolated and who were prescribed an antibiotic, 91 (74%) received only antibiotics to which their isolate was not susceptible.

Case-control study of risk factors for bloody diarrhea. We enrolled 97 cases and 146 controls. Cases were older than other persons with bloody diarrhea in our surveillance study (median age = 31 versus 26 years, respectively; $P = 0.01$). Only five (5%) cases were less than five years old, compared with 17% of all persons with bloody diarrhea identified through surveillance. Cases did not differ from other surveillance patients by sex, village of residence, bacterial isolation rates, or the proportional distribution of bacterial species isolated (Table 2).

Among the approximately 120 risk factors about which we inquired, univariate analysis identified 11 that were significantly or nearly significantly associated with bloody diarrhea, six with increased risk, and five with decreased risk (Table 3). Exposures that did not alter risk for bloody diarrhea included drinking boiled water from any source, presence of soap or a latrine at the home compound, frequency of latrine use, distance of latrines from the home compound's food preparation area, presence of human feces in the home compound yard, eating at a funeral within seven days of illness onset, density of buildings and rooms in the home compound, methods for water storage, and methods for removing water from storage vessels.

In multivariable analysis, two exposures remained independently and significantly associated with increased risk of bloody diarrhea: drinking water from Lake Victoria (the major source of water for all uses in this community) within seven days of clinic presentation (MOR = 4.13, 95% CI = 1.68–10.15) and allowing other families to use the compound latrine (MOR = 2.76, 95% CI = 1.26–6.06). Two exposures remained independently and significantly associated with decreased risk of bloody diarrhea: washing hands after defecating (MOR = 0.29, 95% CI = 0.11–0.79) and eating food from a street vendor within seven days of clinic presentation (MOR = 0.26, 95% CI = 0.13–0.52). We calculated that 27% of the illnesses could have been potentially averted by not drinking Lake Victoria water and 22% of the illnesses by not allowing other families to use the home compound latrine. Washing

TABLE 3

Frequency of selected exposures among cases and controls: dysentery case-control study, Asembo Bay, Kenya, May 1997–September 1999*

Exposure	Cases, n/N (%)	Controls, n/N (%)	MOR	95% CI	*P*
Used as a source of drinking water during the last 7 days					
Borehole (well)	27/97 (28)	61/146 (42)	0.53	0.28, 1.04	0.06
Stream/river	12/97 (12)	6/146 (4)	3.04	1.06, 8.67	0.04
Lake Victoria	35/97 (36)	25/146 (17)	2.22	1.06, 4.64	0.03
Purchased water from the following sources in the last 7 days					
Rainwater	6/95 (6)	2/146 (1)	5.70	1.06, 30.7	0.04
Lake Victoria	15/97 (15)	5/146 (3)	3.52	1.17, 10.6	0.02
Regarding general hygiene					
Washed hands after defecating	79/95 (83)	138/146 (94)	0.34	0.14, 0.84	0.02
Washed hands before preparing food	49/88 (56)	52/145 (36)	0.54	0.29, 1.01	0.05
Allowed other families to use their latrine	34/94 (36)	32/145 (22)	2.40	1.19, 4.84	0.01
Ate food from the following places in the last 7 days					
Another compound (family or friend)	38/95 (52)	76/146 (52)	0.57	0.31, 1.05	0.07
Restaurant	11/96 (11)	7/145 (5)	2.08	1.02, 4.22	0.04
Street vendor	31/96 (32)	92/146 (63)	0.29	0.16, 0.53	<0.01

* n/N = number exposed/total; MOR = maximum likelihood of matched odds ratio by conditional logistic regression; CI = confidence interval.

hands after defecating averted 67% of the illnesses that could have potentially occurred, and eating food from a street vendor averted 48% of the potential illnesses.

DISCUSSION

Similar to previous studies in Africa, we found that *Shigella* predominated as a cause of sporadic bloody diarrhea,[2,18–21] particularly *S. flexneri*. No outbreaks of *S. dysenteriae* type 1 were detected during the four years of surveillance. We found that *Campylobacter* and *Shigella* were isolated with equal frequency from children less than five years old with bloody diarrhea. In comparable studies of semi-urban Bolivian children less than five years old[22] and Thai children 1–10 years of age[23] with bloody diarrhea, *Campylobacter* was isolated at least half as frequently as *Shigella*. Although *Campylobacter* infections are among the most common causes of childhood bacterial diarrhea in developing countries, young children in these circumstances also exhibit high rates of asymptomatic *Campylobacter* carriage.[24,25] We did not culture stool from healthy children to more definitively quantify *Campylobacter*'s contribution to bloody diarrhea; early in the study we found that requesting stool specimens from persons without diarrhea substantially reduced recruitment of controls. Previously published data from this same surveillance system showed asymptomatic carriage rates for *Campylobacter, Shigella,* and *Salmonella* among 100 persons (mostly adults > 18 years old) of 8%, 3%, and 2%, respectively.[12]

We found a high level of resistance to the antibiotics most commonly prescribed; 74% of persons with bloody diarrhea (excluding *Campylobacter*) received antibiotics to which their isolate was not susceptible. Our data were inadequate to assess the clinical impact of these findings (e.g., duration of bloody diarrhea, mortality, or bacterial shedding). Nonetheless, strategies to improve prescription practices that use surveillance data to rationally guide more judicious antibiotic use warrant consideration.

We identified no resistance to ciprofloxacin and minimal resistance to nalidixic acid. Other studies have also found little resistance to nalidixic acid and/or no resistance to ciprofloxacin among *Shigella* in East Africa[26–29] and in other African countries.[19,20,30–36] However, in areas where nalidixic acid has been introduced as the drug of choice to treat presumptive shigellosis, a marked increase in corresponding resistance has been observed.[8,16,31–35] The ease with which antibiotics can be obtained without prescription may add further to selective pressure.[36] Thus, although nalidixic acid is an attractive choice for treating bloody diarrhea where antimicrobial resistance limits other options, it should be used ideally only for illnesses most likely caused by *Shigella* or where *Shigella* infection could result in greater morbidity and increased risk of death (e.g., persons with acquired immunodeficiency syndrome [AIDS]). Retail availability of nalidixic acid should be controlled to prevent broad and indiscriminate use. If nalidixic acid is introduced for routine treatment of bloody diarrhea, surveillance for antimicrobial susceptibility of local bacterial pathogens should be maintained.

The case-control study identified several opportunities for primary prevention of bloody diarrhea that could decrease the overall need for antibiotics. Drinking water from Lake Victoria increased risk. Investigation of a 1997 cholera outbreak in this community also implicated water from Lake Victoria as a risk for enteric illness.[37] Ponds, streams, and other surface sources, including Lake Victoria, are used for bathing, washing clothes, and watering livestock, leading to contamination with human and animal waste. During dry seasons when rainwater and borehole water are less available, disinfecting drinking water from available surface sources may substantially reduce illness.

Sharing latrines has been previously associated with an increased risk of infection with epidemic *S.* dysenteriae type 1.[38] In this study, sharing latrines increased risk for sporadic bloody diarrhea as well. This practice may increase community exposure to infected feces; building more latrines could potentially reduce cases of bloody diarrhea.

Washing hands after defecating was protective, a finding also consistent with other studies.[39] It has been estimated that the attributable risk for dysentery from not washing hands before preparing food in rural African communities is as high as 30%.[40] Handwashing, especially if soap is used, substantially reduces both primary *Shigella* infections and secondary transmission.[41]

The observation that street vendor foods were protective contradicts the findings of numerous previous investigations.[38,39,42–44] These studies were all conducted in urban or peri-urban settings. In this rural community, vended foods and beverages were unique insofar as they typically included items considered safe from bacterial contamination: fruits with thick peels (e.g., bananas), bottled carbonated beverages, and cooked foods served hot (e.g., roasted corn, fried dough). Street vendors did not generally sell water or cold precooked foods. The ability to purchase street vended foods may also be a marker for greater socioeconomic status, an alternate explanation that could confound these results and for which we did not have information.

Our bacterial isolation rates during this study of sporadic bloody diarrhea (overall = 51%, *Shigella* = 44%) compare favorably with the rates reported from a cross-sectional survey for *Shigella* from a comparable survey in rural Uganda (isolation rate = 35%)[28] and during outbreaks of *S. dysenteriae* type 1 in Burundi and Rwanda (isolation rates = 20–73%).[8,34,45] We did not examine stool for parasites; however, their contribution to the burden of bloody diarrhea illness is probably low in this community. Examination of a convenience sample of 75 whole stools collected from our surveillance sites between April and November 1997, which included 17 specimens from persons with bloody diarrhea, demonstrated no *Entamoeba*, *Schistosoma*, or other parasitic infections potentially associated with dysentery (CDC, unpublished data). A study of acute bloody diarrhea in a comparable population of adults in Malawi during 1995 found 8% of specimens yielded *Schistosoma mansoni* as the sole pathogen, no specimens yielded only *Entamoeba*, and 22% yielded only *Shigella*.[20] In a study of bloody diarrhea specimens collected during an *S. dysenteriae* type 1 outbreak in Burundi, six of 107 specimens without *S. dysenteriae* type 1 (6%) yielded *E. histolytica*, of which one also yielded *S. flexneri*.[8] Enteric viruses are not known to cause bloody diarrhea and we did not examine for these agents. Other bacteria for which we did not culture may have caused bloody diarrhea (e.g., enteropathogenic *E. coli*). Inadequate bacterial inoculums in cultured stools may have also reduced yield. Although presence of antibiotics in stool can suppress bacterial growth, we ob-

served no difference in the bacterial isolation rates from persons who reported having taken an antibiotic before specimen collection compared with persons who did not.

Infection with HIV may be an important comorbidity for bloody diarrhea illness in this community, where an estimated 22% of young adults are infected.[14] We were unable to ascertain study participants' HIV status and therefore cannot compare the burden of disease and its etiologies among HIV-infected and uninfected persons. The bimodal peak incidence of sporadic bloody diarrhea in children less than five years old and young adults 20–29 years old is consistent with at least one previous observation of sporadic *Shigella* infections in the pre-AIDS era.[46] It is also possible that the greater incidence of bloody diarrhea we observed among young adults reflects the greater burden of HIV infection in this age group.

This study had additional limitations. The case-control investigation did not assess risk associated with recent contact with another person with bloody diarrhea or with antimicrobial use preceding illness, factors that are both associated with increased risk of epidemic *S. dysenteriae* type 1 infection.[8] Fewer then 5% of the persons enrolled in our case-control study were 0–4 years old, limiting our ability to examine risk factors that may be unique to young children, in whom we found *Campylobacter* to be as common a cause of bloody diarrhea as *Shigella*.

In summary, *Shigella* causes most sporadic bloody diarrhea in western Kenya, although *Campylobacter* may account for a large fraction of illnesses in children less than five years old. There is substantial resistance among *Shigella* to the antibiotics most frequently prescribed for bloody diarrhea, and many persons receive medication to which their infecting bacteria are not susceptible. Providing access to safe drinking water and to latrines, and promoting hand washing could substantially reduce the incidence of bloody diarrhea, the resultant need for antibiotics, and the pressures favoring increased antimicrobial resistance.

Received December 26, 2002. Accepted for publication March 3, 2003.

Acknowledgments: We thank Mark Eberhard, Kimberly Won, John Gimnig, and Allen Hightower (Centers for Disease Control and Prevention), and Judith Achieng, Judith Akuku, Charles Ayuyo, Helen Moige, Henry Moseti, Vincent Nyadwa, Benjamin Ochieng, George Ochola, Caleb Okonji, Johnson Okulo, Sophie Odhiambo, Daniel Ogaja, Lucy Okuogo, Johnson Okulo, Samuel Olango, Maurice Ombok, Nicholas Omondi, Joseph Orurre, Julius Otieno, Jane Oyiengo, Eric Shoute, Rosemary Wanga, Boaz Watanga, and William Yongo, (Kenya Medical Research Institute) for helping with this study. We also thank Dr. Davey Koech (Director of the Kenya Medical Research Institute) for his permission to publish this paper.

Authors' addresses: John T. Brooks, National Center for HIV, STD and TB Prevention, Centers for Disease Control and Prevention, 1600 Clifton Road NE, Mailstop E-45 Atlanta, GA 30333, Telephone: 404-639-3894, Fax: 404-639-6127, E-mail: zud4@cdc.gov. Roger L. Shapiro, Infectious Disease Division, Beth Israel Deaconess Medical Center, 330 Brookline Avenue, Kennedy 6, Boston, MA 02215, Telephone: 617-632-7706, Fax: 617-632-7626. Lata Kumar, Joy G. Wells, and Eric Mintz, Foodborne and Diarrheal Diseases Branch, Division of Bacterial and Mycotic Diseases, National Center for Infectious Diseases, Centers for Disease Control and Prevention, Mailstop A-38, 1600 Clifton Road NE, Atlanta, GA 30333, Telephone: 404-639-2206, Fax: 404-639-2205. Penelope A. Phillips-Howard, Division of Parasitic Diseases, National Center for Infectious Diseases, Centers for Disease Control and Prevention, Mailstop F-22, 4770 Buford Highway, Atlanta, GA 30341. Ya-Ping Shi, John M. Vulule, and Laurence Slutsker, Centers for Disease Control and Prevention/Kenya Medical Research Institute Field Station, PO Box 1578, Kisumu, Kenya, Telephone: 254-35-22902, Fax: 254-35-22981. Robert M. Hoekstra, Biostatistics and Information Management Branch, Division of Bacterial and Mycotic Diseases, National Center for Infectious Diseases, Centers for Disease Control and Prevention, Mailstop C-09, 1600 Clifton Road NE, Atlanta, GA 30333, Telephone: 404-639-4712.

Reprint requests: Foodborne and Diarrheal Diseases Branch, Division of Bacterial and Mycotic Diseases, National Center for Infectious Diseases, Centers for Disease Control and Prevention, Mailstop A-38, 1600 Clifton Road NE, Atlanta, GA 30333.

REFERENCES

1. WHO, 1999. *World Health Report 1999*. Geneva: World Health Organization.
2. Ronsmans C, Bennish ML, Wierzba T, 1988. Diagnosis and management of dysentery by community health workers. *Lancet 2:* 552–555.
3. Henry FJ, 1991. The epidemiologic importance of dysentery in communities. *Rev Infect Dis 13:* S238–S244.
4. WHO, 1995. *Guidelines for the Control of Epidemics Due to Shigella dysenteriae 1.* Geneva: World Health Organization.
5. 2000. *Red Book*, *Report of the Committee on Infectious Diseases*. Elk Grove, IL: American Academy of Pediatrics.
6. Guerrant RL, van Gilder T, Steiner TS, Thielman NM, Slutsker L, Tauxe RV, Hennessy T, Griffin PM, DuPont H, Sack RB, Tarr P, Neill M, Nachamkin I, Reller LB, Osterholm MT, Bennish ML, Pickering LK, 2001. Practice guidelines for the management of infectious diarrhea. *Clin Infect Dis 32:* 331–351.
7. Sack DA, Lyke C, McLaughlin C, Suwanvanichkij V, 2001. *Antimicrobial Resistance in Shigellosis, Cholera, and Campylobacteriosis.* Geneva: World Health Organization.
8. Ries AA, Wells JG, Olivola D, Ntakibirora M, Nyandwi S, Ntibakivayo M, Ivey CB, Greene KD, Tenover FC, Wahlquist SP, Griffin PM, Tauxe RV, 1994. Epidemic *Shigella dysenteriae* type 1 in Burundi: panresistance and implications for prevention. *J Infect Dis 169:* 1035–1041.
9. Butler T, Islam MR, Azad MA, Jones PK, 1987. Risk factors for development of hemolytic uremic syndrome during shigellosis. *J Pediatr 110:* 894–897.
10. Legros D, Paquet C, Dorlencourt F, Le Saoult E, 1999. Risk factors for death in hospitalized dysentery patients in Rwanda. *Trop Med Int Health 4:* 428–432.
11. Malakooti MA, Allai J, Shanks GD, Phillips-Howard PA, 1997. Epidemic dysentery in western Kenya. *Trans R Soc Trop Med Hyg 91:* 541–543.
12. Shapiro RL, Kumar L, Phillips-Howard P, Wells JG, Adcock P, Brooks J, Ackers ML, Ochieng JB, Mintz E, Wahlquist S, Waiyaki P, Slutsker L, 2001. Antimicrobial-resistant bacterial diarrhea in rural western Kenya. *J Infect Dis 183:* 1701–1704.
13. Shori R, 2000. Impact of socio-economic indicators on the health of children in Kenya households, with emphasis on poverty, malnutrition, childhood mortality, morbidity, and HIV/AIDS. Malaguerra C, Fust W, eds. *International Association for Official Statistics Conference on "Statistics, Development and Human Rights."* Montreux, Switzerland: International Association for Official Statistics.
14. 2001. *AIDS in Kenya: Background, Projections, Impact, Interventions, and Policy*. Sixth edition. Nairobi, Kenya: Kenya Ministry of Health, National AIDS and STD Control.
15. Olsvik O, Rimstad E, Hornes E, Strockbine N, Wasteson Y, Lund A, Wachsmuth K, 1991. A nested PCR followed by magnetic separation of amplified fragments for detection of *Escherichia coli* Shiga-like toxin genes. *Mol Cell Probes 5:* 429–435.
16. Karch H, Bohm H, Schmidt H, Gunzer F, Aleksic S, Heesemann J, 1993. Clonal structure and pathogenicity of Shiga-like toxin-producing, sorbitol-fermenting *Escherichia coli* O157:H-. *J Clin Microbiol 31:* 1200–1205.
17. 1998. *Performance Standards for Antimicrobial Disk Diffusion Susceptibility Tests: 8th Informational Supplement.* NCCLS Document M100S8. Villanova, PA: National Committee for Clinical Laboratory Standards.

18. Nakano T, Binka FN, Afari EA, Agbodaze D, Aryeetey ME, Mingle JAA, Kamiya H, Sakurai M, 1990. Survey of enteropathogenic agents in children with and without diarrhoea in Ghana. *J Trop Med Hyg 93:* 408–412.
19. Adeleye IA, Adetosoye AI, 1993. Antimicrobial resistance patterns and plasmid survey of *Salmonella* and *Shigella* isolated is Ibadan, Nigeria. *East Afr Med J 70:* 259–262.
20. Pitman C, Amali R, Kanyerere H, Siyasiya A, Phiri S, Phiri A, Chakanika I, Kampondeni S, Chintolo FE, Kachenje E, Squire SB, 1996. Bloody diarrhea of adults in Malawi: clinical features, infectious agents, and antimicrobial sensitivities. *Trans R SocTrop Med Hyg 90:* 284–287.
21. Nakano T, Kamiya H, Matsubayashi N, Watanabe M, Sakurai M, Honda T, 1998. Diagnosis of bacterial enteric infections in children in Zambia. *Acta Paediatr Jpn 40:* 259–263.
22. Townes JM, Quick R, Gonzales OY, Linares M, Damiani E, Bopp CA, Wahlquist SP, Hutwanger LC, Hanover E, Mintz ED, Tauxe RV, 1997. Etiology of bloody diarrhea in Bolivian children: implications for empiric therapy. *J Infect Dis 175:* 1527–1530.
23. Taylor D, Bodhidatta L, Echeverria P, 1991. Epidemiologic aspects of shigellosis and other causes of dysentery in Thailand. *Rev Infect Dis 13:* S226–S230.
24. Coker AO, Isokpehi RD, Thomas BN, Amisu KO, Obi CL, 2002. Human campylobacteriosis in developing countries. *Emerg Infect Dis 8:* 237–243.
25. Oberhelman RA, Taylor DN, 2000. *Campylobacter* infections in developing countries. Nachamkin I, Blaser MJ, eds. *Campylobacter*. Washington, DC: American Society for Microbiology, 139–153.
26. Kruse H, Kariuki S, Soli N, Olsvik O, 1992. Multiresistant *Shigella* species from African AIDS patients: antibacterial resistance patterns and application of E-test for determination of minimal inhibitory concentration. *Scand J Infect Dis 2:* 733–739.
27. Materu SF, Lema OE, Mukunza HM, Adhiambo CG, Carter JY, 1997. Antibiotic resistance patterns of *Vibrio cholerae* and *Shigella* causing diarrhoea outbreaks in the eastern African region. *East Afr Med J 74:* 193–197.
28. Legros D, Ochola D, Lwanga N, Guma G, 1998. Antibiotic sensitivity of endemic *Shigella* in Mbarara, Uganda. *East Afr Med J 75:* 160–161.
29. Navia MM, Capitano L, Ruiz J, Vargas M, Urassa H, Schellemberg D, Gascon J, Vila J, 1999. Typing and characterization of mechanisms of resistance of *Shigella* spp. isolated from feces of children under 5 years of age from Ifakara, Tanzania. *J Clin Microbiol 37:* 3113–3117.
30. Iwalokun BA, Gbenle GO, Smith SI, Ogunledun A, Akinsinde KA, Omonigbehin EA, 2001. Epidemiology of shigellosis in Lagos, Nigeria: trends in antimicrobial resistance. *J Health Popul Nutr 19:* 183–190.
31. Panhotra BR, Desai B, Sharma PL, 1985. Nalidixic-acid-resistant *Shigella dysenteriae* 1. *Lancet 1:* 763.
32. Mutwewingabo A, Mets T, 1987. Increase in multiresistance of *Shigella dysenteriae* type 1 strain in Rwanda. *East Afr Med J 64:* 812–815.
33. Munshi MH, Sack DA, Haider K, Ahmed ZU, Rahaman MM, Morshed MG, 1987. Plasmid-mediated resistance to nalidixic acid in *Shigella dysenteriae* type 1. *Lancet 2:* 419–421.
34. Paquet C, Leborgne P, Sasse A, Varaine F, 1995. An outbreak of *Shigella dysenteriae* type 1 dysentery in a Rwandan refugee camp. *Sante 5:* 181–184.
35. Ahmed F, Clemens JD, Rao MR, Ansaruzzaman M, Haque E, 1997. Epidemiology of shigellosis among children exposed to cases of *Shigella* dysentery: a multivariate assessment. *Am J Trop Med Hyg 56:* 258–264.
36. WHO, 1999. *Containing Antimicrobial Resistance: Review of the Literature and Report of a WHO Workshop on the Development of a Global Strategy for the Containment of Antimicrobial Resistance*. Geneva: World Health Organization.
37. Shapiro RL, Otieno MR, Adcock PM, Phillips-Howard PA, Hawley WA, Kumar L, Waiyaki P, Nahlen BL, Slutsker L, 1999. Transmission of epidemic *Vibrio cholerae* O1 in rural western Kenya associated with drinking water from Lake Victoria: an environmental reservoir for cholera? *Am J Trop Med Hyg 60:* 271–276.
38. Tuttle J, Ries AA, Chimba RM, Perera CU, Bean NA, Griffin PM, 1995. Antimicrobial-resistant epidemic *Shigella dysenteriae* type 1 in Zambia: modes of transmission. *J Infect Dis 171:* 371–375.
39. Gasem MH, Dolmans WM, Keuter MM, Djokomoeljanto RR, 2001. Poor food hygiene and housing as risk factors for typhoid fever in Semarang, Indonesia. *Trop Med Int Health 6:* 484–490.
40. Birmingham ME, Lee LA, Ntakibirora M, Bizimana F, Deming MS, 1997. A household survey of dysentery in Burundi: implications for the current pandemic in sub-Saharan Africa. *Bull World Health Organ 75:* 45–53.
41. Khan MU, 1982. Interruption of shigellosis by hand washing. *Trans R Soc Trop Med Hyg 76:* 164–168.
42. Weber JT, Mintz ED, Canizares R, Semiglia A, Gomez I, Sempertegui R, Davila A, Greene KD, Puhr ND, Cameron DN, 1994. Epidemic cholera in Ecuador: multidrug-resistance and transmission by water and seafood. *Epidemiol Infect 112:* 1–11.
43. Koo D, Aragon A, Moscoso V, Gudiel M, Bietti L, Carrillo N, Chojoj J, Gordillo B, Cano F, Cameron DN, Wells JG, Bean NH, Tauxe RV, 1996. Epidemic cholera in Guatemala, 1993: transmission of a newly introduced epidemic strain by street vendors. *Epidemiol Infect 116:* 121–126.
44. Luby SP, Faizan MK, Fisher-Hoch SP, Syed A, Mintz ED, Bhutta ZA, McCormick JB, 1998. Risk factors for typhoid fever in an endemic setting, Karachi, Pakistan. *Epidemiol Infect 120:* 129–138.
45. Engels D, Madaras T, Nyandwi S, Murray J, 1995. Epidemic dysentery caused by *Shigella dysenteriae* type 1: a sentinel site surveilllance of antibiotic resistance patterns in Burundi. *Bull World Health Organ 73:* 787–791.
46. Chiron JP, Denis F, Samb A, Sow A, Diop Mar I, 1977. Incidence of shigellosis in Dakar hospitals during a four-year period, 1973-1976. *Bull Soc Med Afr Noire Lange Francaise 22:* 174–180.