**150th Anniversary of John Snow and the Pump Handle**

John Snow, M.D. (1813–1858), a legendary figure in epidemiology, provided one of the earliest examples of using epidemiologic methods to identify risk for disease and recommend preventive action (1). Best known for his work in anesthesiology, Snow also had an interest in cholera and supported the unpopular theory that cholera was transmitted by water rather than through miasma (i.e., bad air).

On August 31, 1854, London experienced a recurrent epidemic of cholera; Snow suspected water from the Broad Street pump as the source of disease. To test his theory, Snow reviewed death records of area residents who died from cholera and interviewed household members, documenting that most deceased persons had lived near and had drunk water from the pump. Snow presented his findings to community leaders, and the pump handle was removed on September 8, 1854. Removal of the handle prevented additional cholera deaths, supporting Snow’s theory that cholera was a waterborne, contagious disease. Despite the success of this investigation, the cause of cholera remained a matter of debate until *Vibrio cholerae* was isolated in 1883.

Snow’s studies and the removal of the pump handle became a model for modern epidemiology. To recognize his pioneering work, this issue of *MMWR* highlights public health actions guided by epidemiologic data to control a modern epidemic of cholera, detect and prevent adverse reactions to vaccinations, stop an epidemic of aflatoxin poisoning, and correct environmental causes of waterborne outbreaks.

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Zambia experienced widespread cholera epidemics in 1991 (13,154 cases), 1992 (11,659), and 1999 (11,327) (1). In response to the large outbreak in 1999, the Zambian Ministry of Health (ZMOH) urged use of in-home chlorination with the locally produced solution, Clorin®, and the practice increased substantially Clorin® had been introduced in Zambia in 1998 as part of the Safe Water System (SWS), a point-of-use water disinfection and safe-water storage strategy* launched by the Society for Family Health, in partnership with ZMOH, the U.S. Agency for International Development, and CDC. Although no outbreaks were reported during 2000–2002, cholera remained endemic. Epidemic cholera returned to Zambia in November 2003, when cases of toxigenic *Vibrio cholerae* O1, serotype Ogawa, biotype El Tor were confirmed in the capital city, Lusaka. During November 28, 2003–January 4, 2004, an estimated 2,529 cholera cases and 128 cholera deaths (case-fatality rate [CFR] = 5.1%) occurred in Lusaka. In February 2004, the Lusaka District Health Management Team (LDHMT) invited CDC to assist in an


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investigation of the epidemic. This report summarizes the results of that investigation, which implicated foodborne transmission via raw vegetables and demonstrated a protective role for hand washing with soap. The results underscore the importance of hygiene, clean water, and sanitary food handling for cholera prevention.

In response to increasing cases, Zambian authorities began opening designated cholera-treatment centers (CTCs) in Lusaka in December 2003. All seven CTCs were functional by early January 2004, and all patients with suspected cholera were referred to these facilities. During January 5–March 1, an additional 2,101 cases and 25 deaths from cholera (CFR = 1.2%) were recorded at CTCs in Lusaka. Investigators conducted a matched case-control study to identify risk factors for cholera. A case was defined as watery diarrhea in a person aged ≥5 years, who was admitted to the Chawama (Figure) or Kanyama CTC during February 11–22. Stool cultures were performed for all eligible patients. Homes of enrolled patients were visited, and one age-, sex-, and neighborhood-matched control per case was selected systematically from neighboring households.

A total of 71 case-control pairs were enrolled in the study. *V. cholerae* O1 was identified in stool cultures from 52 (74%) patients. Both bivariate and multivariate analyses were performed, comparing all cases with culture-confirmed cases; because data were comparable for the two groups, results are reported for all cases in aggregate. The median age of patients was 27 years (range: 5–75 years); 58% were male. Common
symptoms, in addition to diarrhea, included vomiting (61 [86%]) and leg cramps (44 [62%]).

Bivariate analysis indicated that consumption of raw vegetables was associated with cholera (matched odds ratio [MOR] = 3.9; 95% confidence interval [CI] = 1.7–9.6; p = 0.0004). Hand soap was observed in 41 (58%) case homes and 64 (90%) control homes. Presence of hand soap was considered a proxy for actual hand washing and was determined to be protective (MOR = 0.14; 95% CI = 0.05–0.40; p = 0.0001). Consumption of kapenta, a local sardine-like dietary staple, also was protective (MOR = 0.35; 95% CI = 0.2–0.8; p = 0.005). Drinking untreated water was reported by 48 (67%) case-patients and 37 (52%) controls, but the association with disease did not reach statistical significance (MOR = 1.9; 95% CI = 0.9–3.9; p = 0.06). In-home chlorination of drinking water with Clorin® reported by 48 (67%) controls and 47 (66%) case-patients. Free chlorine residuals were detected in stored water in 19 (27%) case homes and 14 (20%) control homes (MOR = 1.5; 95% CI = 0.7–3.3; p = 0.21).

Kapenta, raw vegetables, presence of soap, and in-home water treatment were included in a multivariate model. Water treatment, either by boiling or home chlorination, was not significantly protective. Consumption of raw vegetables remained significantly associated with cholera (adjusted odds ratio [AOR] = 4.7; 95% CI = 1.7–13.0). The presence of hand soap remained significantly protective against cholera (AOR = 0.1; 95% CI = 0.04–0.40), as did consumption of kapenta (AOR = 0.3; 95% CI = 0.1–0.7).

On the basis of these results, the Zambian Central Board of Health and LDHMT enhanced cholera-prevention efforts by reinforcing hand-washing promotion messages and recommending that vegetables be cooked or washed in treated water. Plans were created to improve hygiene and increase availability of latrines at Lusaka’s major market to minimize cross-contamination of produce. Long-term prevention measures under discussion by local authorities include improving the quality and quantity of municipal water supplies. In April, cholera cases declined dramatically, and LDHMT closed the CTCs.

Reported by: M Sinkala, MD, M Makasa, MD, F Mwanza, P Mulenga, Lusaka District Health Management Team, Zambia; P Kalluri, MD, R Quick, MD, E Mintz, MD, RM Hoekstra, PhD, Div of Bacterial and Mycotic Diseases, National Center for Infectious Diseases; A DuBois, MD, EIS Officer, CDC.

Editorial Note: This month marks the 150th anniversary of the removal of the famed Broad Street pump handle after John Snow's classic study of epidemic cholera in London. Cholera is caused by toxigenic V. cholerae, serogroup O1 or O139. Infection can result in rapidly progressive, profuse, dehydrating diarrhea, with CFRs ≥22% when treatment is delayed (2). Cholera, which is still propagated by many of the same vehicles described by John Snow in the mid-1800s (3), remains a public health threat in sub-Saharan Africa and certain Asian countries. In 2003, the World Health Organization reported a total of 111,575 cholera cases and 1,894 deaths (CFR = 1.7%) in 45 countries; 97% of reported cases occurred in sub-Saharan Africa (4). In recent decades, the CFR of cholera has decreased because of dramatic improvements in oral and intravenous rehydration therapy (5).

In this epidemic of cholera, the primary mode of transmission was foodborne rather than waterborne, a possibility recognized by Snow (3). The implication of vegetables as a vehicle of transmission in this epidemic emphasizes the need for further assessment of produce hygiene during transport, delivery, and use in the home.

This investigation also documented the widespread acceptance of the SWS in cholera-affected communities in Lusaka. Implemented as a pilot project in Zambia in 1998, SWS has been determined to reduce the risk for diarrhea by ≥40% (7). The SWS consists of Clorin®, a dilute solution of locally produced sodium hypochlorite bleach, packaged and marketed for disinfection of water in the home, and promotion of plastic 20-liter jerricans for safe storage of treated water. The demand for Clorin® escalated during the 1999 cholera epidemic, and sales increased steadily in subsequent years. In 2003, approximately 1.7 million bottles of Clorin® were sold in Zambia. Findings of this investigation suggest that, 5 years after introduction of the SWS in Zambia, >20% of persons residing in Lusaka’s shantytown purchase Clorin® solution and add it to their water.

The presence of soap in the home, which serves as a proxy for improved hygiene, was protective against cholera during this investigation. This finding is consistent with other studies that suggest hand washing reduces the risk for diarrhea by >40% (8) and echoes the work of Snow, who implicated poor hand hygiene in cholera transmission.

Approximately 50% of Zambia’s 10 million residents live in cities. An estimated 60% of the 2 million residents of Lusaka reside in shantytowns without municipal water supplies or sewer systems (9). Snow’s London of 1854 resembles numerous cities in the developing world today, where inadequate water and sanitation services and overcrowding contribute to a high burden of preventable diseases such as cholera. An estimated 1.1 billion persons in the world live without access to improved water supplies such as piped municipal systems; hundreds of millions more use inadequate systems, which
routinely provide water that is contaminated and unsafe. Waterborne transmission of enteric pathogens contributes to the estimated 2 million diarrheal deaths that occur among children aged <5 years each year (10). In recognition of this continuing problem, member states of the United Nations established a Millennium Development Goal for Water to reduce by half the proportion of persons without sustainable access to safe drinking water by 2015. To achieve this goal, an estimated 300,000 persons must gain access to safe drinking water each day for the next 11 years. Even if this challenge is met, more than half a billion persons will still lack access to safe drinking water. As in Snow’s day, field epidemiology and practical prevention strategies remain critical to meeting public health challenges in the modern world.

Acknowledgments


References


Suspension of Rotavirus Vaccine After Reports of Intussusception — United States, 1999

On July 16, 1999, CDC recommended that health-care providers suspend use of the licensed rhesus-human rotavirus reassortant-tetravalent vaccine (RRV-TV) (RotaShield®, Wyeth Laboratories, Inc., Marietta, Pennsylvania) in response to 15 cases of intussusception (i.e., a bowel obstruction in which one segment of bowel becomes enfolded within another segment) among infants who received RRV-TV (1). The Vaccine Adverse Event Reporting System (VAERS) monitored for adverse events following licensure of RRV-TV on August 31, 1999. After the recommendation to suspend use of the vaccine, no additional cases were reported (2). This report describes the surveillance activities used to identify this vaccine adverse event, the emergency response, and follow-up investigations. Suspension of RRV-TV after the initial cases of intussusception parallels the removal of the Broad Street pump handle in response to John Snow’s epidemiologic studies; both were decisive, life-saving public health actions.

VAERS, operated by CDC and the Food and Drug Administration (FDA), is a national passive surveillance system that monitors the safety of vaccines (3). Health-care providers, consumers, and vaccine manufacturers are encouraged to report adverse events involving all U.S.-licensed vaccines. During 1998–1999, CDC and FDA monitored VAERS for reports of intussusception and other severe gastrointestinal events among RRV-TV recipients. As a requirement for FDA licensure, the vaccine manufacturer funded a postlicensure phase IV trial of RRV-TV at Northern California Kaiser Permanente (NCKP) to monitor possible adverse events (4). Intussusception had been observed at low rates in prelicensure clinical trials, but a causal association with the vaccine was not proven; this information and a request for reporting to VAERS were included in the vaccine product label and recommendations of the Advisory Committee on Immunization Practices (ACIP).

During December 18, 1998–June 2, 1999, a total of 10 cases of intussusception were reported to VAERS (Figure 1). Four cases of intussusception involving other vaccines had been reported to VAERS during the preceding 8 years (2,5). The cases appeared to be nonrandom in distribution; among the majority of infants, intussusception occurred after receiving the first dose of RRV-TV and within 1 week after receiving any dose. The temporal clustering after receipt of RRV-TV suggested a causal relationship. These early findings prompted CDC to request data from NCKP and initiate two validation studies, a 19-state case-control study and case-series analysis...