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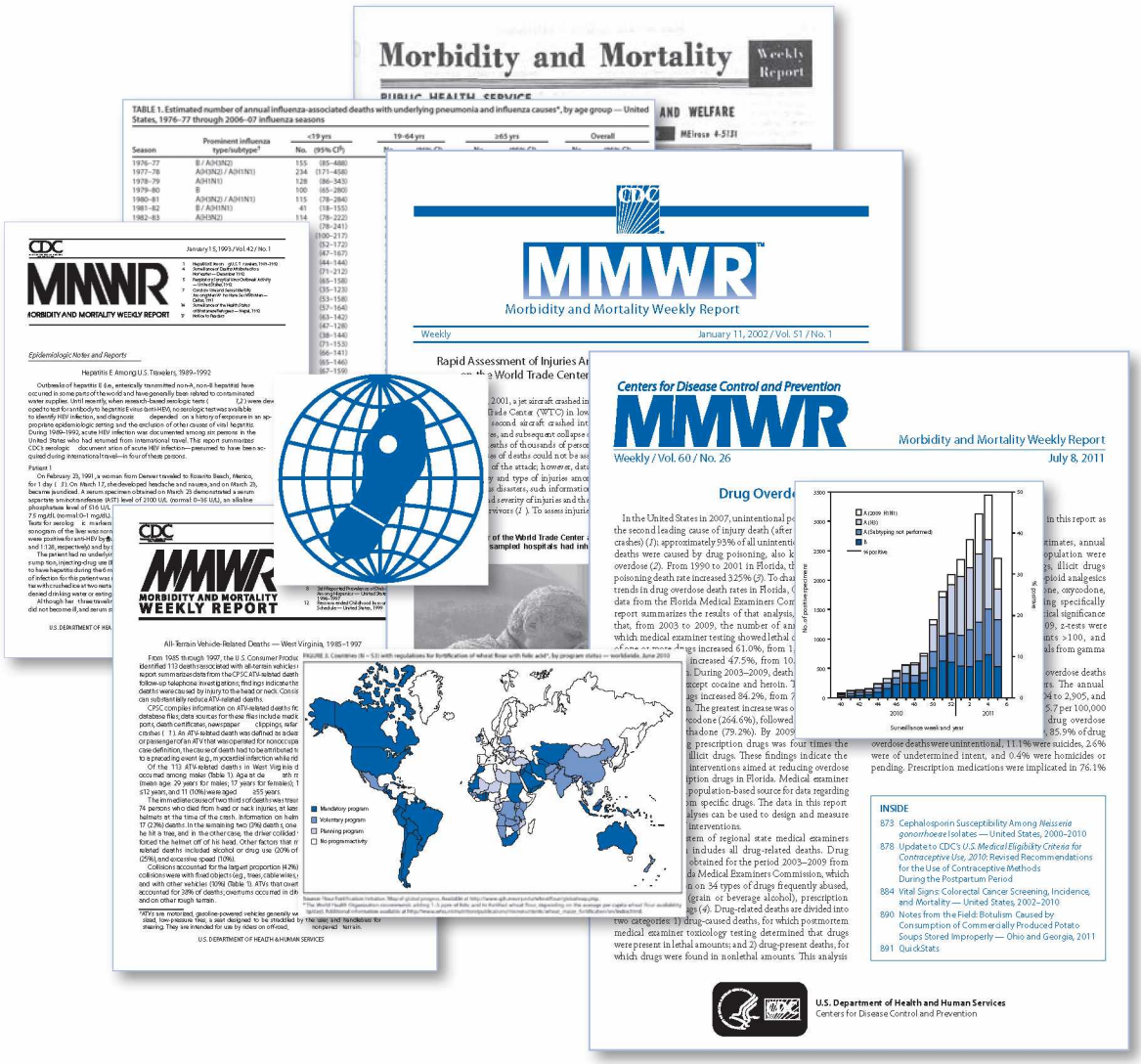
Public Health Then and Now: Celebrating 50 Years of *MMWR* at CDC



U.S. Department of Health and Human Services
Centers for Disease Control and Prevention

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Note to Readers

This supplement includes the individual perspectives of public health professionals external to CDC. Any opinions expressed by these contributors are their own rather than the "voice of CDC."

On the cover: See page 120 for a description of the cover art.

The *MMWR* series of publications is published by the Office of Surveillance, Epidemiology, and Laboratory Services, Centers for Disease Control and Prevention (CDC), U.S. Department of Health and Human Services, Atlanta, GA 30333.

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Foreword

Alexander Langmuir became the first Chief Epidemiologist at CDC (then called the Communicable Disease Center) in 1949. One of his many enduring contributions to the agency and to public health was to engineer the transfer in 1961 of the *Morbidity and Mortality Weekly Report* (*MMWR*) from its former home at the National Office of Vital Statistics to CDC. This supplement to *MMWR* celebrates the anniversary of its arrival at CDC and the 50-year contribution it has made to CDC and public health. Langmuir had the foresight to envision the revitalization of the decades-old publication, not only to enable CDC to share its work with the nation, but also to influence the practice and impact of public health throughout the world. This supplement celebrates *MMWR* through perspectives on how public health has changed during the past 50 years. Articles in this issue reflect on how the focus of public health has expanded from communicable disease to also include a broad array of acute and chronic public health challenges.

Langmuir had a powerful ability to visualize the future but an even more powerful ability to realize his vision through the force of his strong will and his flair for recruiting and mentoring young men and women in public health. *MMWR* was part of his vision, and as its unofficial editor for many years, he demanded high-quality science presented in clear and crisp prose—qualities that have endured to the present day.

Like so many of Langmuir's innovations, *MMWR* has evolved with the years but it has always remained vital to each new challenge. As CDC's flagship publication, *MMWR* documents the impact of public health programs throughout the United States and the world, and in many cases acts as a catalyst for improvement. When health departments or ministries seek CDC's scientific information, often driven by urgent threats to the public's health, they seek out *MMWR* for its clearly crafted scientific articles and reliable clinical and public health recommendations based on the best available science.

In Langmuir's day, issuing a weekly scientific publication was unusual, if not unprecedented, at a federal agency. Langmuir could not have envisioned that his *MMWR* would one day be available 24 hours a day, 7 days a week on computers, cell phones, and portable electronic devices of all kinds. Today *MMWR* is distributed worldwide through both print and electronic media and employs the latest communications technologies, including the Internet, e-mail, social media, and podcasts. As new methods of communication evolve, so will *MMWR*.

Surveillance and epidemiology have always been the cornerstones of public health. The *MMWR* series has provided a mechanism to communicate data from national and international surveillance systems, as well as from epidemiologic, statistical, and laboratory research. During the past 2 decades, terrorism and emergency response, modernization and globalization of the food supply, and a wide range of environmental health threats have dramatically affected public health practice—and these stories have all been carefully told in the pages of *MMWR*.

Many of the most important communicable disease events during the past 50 years have been marked by articles in *MMWR*. Examples include the discovery of the bacterial cause of Legionnaires disease in 1977; the initial reports linking Reye syndrome to salicylates in 1980; the first five published cases of AIDS in 1981; the first report of iatrogenic HIV transmission in 1990; the first case reports of the intentional release of anthrax spores in 2001; the first reports of severe acute respiratory syndrome (SARS) in 2003; and the first two reports of 2009 pandemic influenza A (H1N1) .

Even in its early days at CDC, *MMWR* published many reports on noninfectious diseases, such as pentachlorophenol poisoning in newborn infants in 1967; lead absorption in 1973; angiosarcoma of the liver among workers exposed to polyvinyl chloride in 1974; and acute childhood leukemia in 1976. In recent years, *MMWR* has published more reports on noninfectious diseases, injuries, chronic diseases, and related behaviors (e.g., arthritis, autism spectrum disorder, depression, infant maltreatment, sleep deprivation, and excessive television viewing), and many reports on the leading causes of death: cardiovascular disease, smoking, stroke, obesity, and harmful alcohol use.

In recent decades, behavioral and social science, economics, informatics, and genomics increasingly have contributed to public health, and reports of these have appeared with increasing regularity in *MMWR*. Public health events such as contamination of commercial food products, threats to patient safety in health-care settings, and natural disasters (e.g., the recent floods in the Midwest, heat waves in the Northeast, the earthquake in Haiti, and flooding in Pakistan) will continue to challenge the health infrastructure. In addition, health reform and the coalescence of clinical medicine, veterinary medicine, and public health are creating new opportunities for promoting prevention as the defining concept in improving the health of the public. Innovations such as electronic health records are providing unique opportunities to better understand and improve health care and health status. Through all these changes, *MMWR* will continue reporting on urgent, emerging, and routine public health findings, thereby helping CDC monitor and protect the public's health at home and around the world, and will remain an essential tool for CDC's far-ranging mission.

Thomas R. Frieden, MD
Director, CDC

Introduction

Frederic E. Shaw, MD, JD[1]*
Katrin S. Kohl, MD, PhD[2]
Lisa M. Lee, PhD[1]
Stephen B. Thacker, MD[1]
[1]*Office of Surveillance, Epidemiology and Laboratory Services, CDC, Atlanta, Georgia.*
[2]*Division of Global Migration and Quarantine, National Center for Emerging and Zoonotic Infectious Diseases, CDC, Atlanta, Georgia.*

This supplement of *MMWR* celebrates the 50th anniversary of CDC's first publication of *MMWR* on January 13, 1961 (Figure 1). *MMWR* was not new in 1961, but it was new to CDC, an agency that itself had been founded only 15 years earlier, in 1946 (*1*). The longer history of *MMWR* traces back to July 13, 1878, when the first predecessor of *MMWR*, called simply *The Bulletin of the Public Health*, was inaugurated. The Bulletin was established in accordance with the first National Quarantine Act, passed by Congress 2 months earlier. The Act ordered the Surgeon General of the U.S. Marine-Hospital Service to begin publishing abstracted disease reports collected from U.S. consuls in foreign lands to alert U.S. quarantine officials about what diseases could be expected among passengers arriving on steamships (*2,3*). In the 83 years from 1878 to 1961, *MMWR* went through several incarnations. By 1952, the publication had its current name and was being published by the National Office of Vital Statistics, an agency within the U.S. Department of Health, Education and Welfare. In 1960, CDC's renowned chief of epidemiology, Alexander D. Langmuir, decided that *MMWR* should be transferred to CDC (then known as the Communicable Disease Center). After much discussion, and as Langmuir later said in an interview, "all sorts of pulling out teeth by the roots without anesthesia and all kinds of internal frictions," in 1960, *MMWR* was transferred to CDC (*4*).

In 2009, as the 50th anniversary of *MMWR* loomed, the *MMWR* Editor (F.E.S.) began discussions with leaders at CDC and the *MMWR* Editorial Board about how best to commemorate this date. Members of the Board, editors, and friends of *MMWR* offered many good ideas. In the end, the most persuasive idea was to celebrate the 50th anniversary simply by doing what *MMWR* has done best for 5 decades at CDC: publish articles of high value to its readers. The title of the supplement is "Public Health Then and Now: Celebrating 50 Years of *MMWR* at CDC." The supplement's guest editors (F.E.S., K.S.K., L.M.L., S.B.T.) selected a cadre of expert authors who have long experience in their respective fields of public health—enough to enable them to look back over the past 50 years and trace the most important influences and developments. The guest editors asked the authors to answer three key questions. What was the state of the art in 1961? How did it develop through 50 years into its present form? What does the future hold? Thus, with few exceptions, the 16 articles that make up this supplement are not meant to be about *MMWR* but instead are meant to trace the development of key areas of public health through the 50-year era of *MMWR* at CDC.

The authors took up the challenge admirably. The result is a diverse set of articles that portray public health in 1961 and forward in time to the present and beyond. The articles range from detailed historical review, to analyses of MMWR content, to the more whimsical. They are not meant to be exhaustive, nor can they treat their topics as thoroughly as would a longer text, but they do depict the main events, developments, and innovations that led public health to where it stands today.

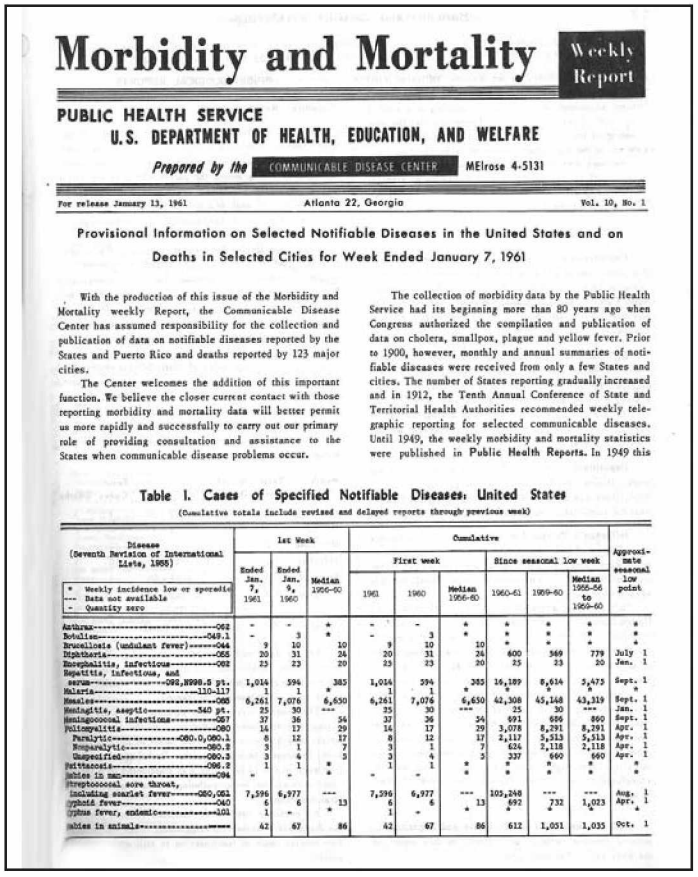
What is *MMWR*?

In 1996, on the occasion of the 50th anniversary of CDC, three long-serving editors of *MMWR* restated the purpose of the publication: "…to report events of public health interest and importance to CDC's major constituents—state and local health departments—and as quickly as possible", and to distribute "… objective scientific information, albeit often preliminary, to the public at large" (*5*). Although the content of *MMWR* has changed since its inception in 1878, by and large it has included three basic elements: 1) short reports about acute public health events, such as outbreaks of infectious diseases, environmental events, clusters of noninfectious diseases, and analyses on the incidence and prevalence of chronic diseases, conditions, or related behaviors; 2) longer reports and supplements on public health surveillance, policy recommendations, and special topics; and 3) statistical tables on the week's morbidity and mortality in the United States, with a wrap-up report published after the end of the surveillance year. Over the years, these elements have changed in scope, complexity, length, and other attributes, but they remain the core of *MMWR*'s content.

MMWR has been the first source of information for many important public health events. Perhaps the best known is an *MMWR* report titled "*Pneumocystis* pneumonia—Los Angeles," which was published on June 5, 1981 (*6*). It described five cases of an immunosuppressive illness in previously healthy

*Editor, MMWR, 2007–2010.

FIGURE 1. Facsimile of the first issue of *MMWR* published at CDC, January 13, 1961



Morbidity and Mortality Weekly Report

PUBLIC HEALTH SERVICE
U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Prepared by the COMMUNICABLE DISEASE CENTER MElrose 4-5131

For release January 13, 1961 — Atlanta 22, Georgia — Vol. 10, No. 1

Provisional Information on Selected Notifiable Diseases in the United States and on Deaths in Selected Cities for Week Ended January 7, 1961

With the production of this issue of the Morbidity and Mortality weekly Report, the Communicable Disease Center has assumed responsibility for the collection and publication of data on notifiable diseases reported by the States and Puerto Rico and deaths reported by 123 major cities.

The Center welcomes the addition of this important function. We believe the closer current contact with those reporting morbidity and mortality data will better permit us more rapidly and successfully to carry out our primary role of providing consultation and assistance to the States when communicable disease problems occur.

The collection of morbidity data by the Public Health Service had its beginning more than 80 years ago when Congress authorized the compilation and publication of data on cholera, smallpox, plague and yellow fever. Prior to 1900, however, monthly and annual summaries of notifiable diseases were received from only a few States and cities. The number of States reporting gradually increased and in 1912, the Tenth Annual Conference of State and Territorial Health Authorities recommended weekly telegraphic reporting for selected communicable diseases. Until 1949, the weekly morbidity and mortality statistics were published in Public Health Reports. In 1949 this

Table I. Cases of Specified Notifiable Diseases: United States

(Cumulative totals include revised and delayed reports through previous week)

Disease (Seventh Revision of International Lists, 1955)	1st Week			Cumulative						Approximate seasonal low point
				First week			Since seasonal low week			
* Weekly incidence low or sporadic --- Data not available - Quantity zero	Ended Jan. 7, 1961	Ended Jan. 9, 1960	Median 1956-60	1961	1960	Median 1956-60	1960-61	1959-60	Median 1956-56 to 1959-60	
Anthrax-----062	-	-	*	-	-	*	*	*	*	*
Botulism-----049.1	-	3	*	-	3	*	*	*	*	*
Brucellosis (undulant fever)-----044	9	10	10	9	10	10	*	*	*	*
Diphtheria-----055	20	31	24	20	31	24	600	369	779	July 1
Encephalitis, infectious-----062	23	23	20	23	23	20	25	23	20	Jan. 1
Hepatitis, infectious, and serum-----092,B990.5 pt.	1,014	594	385	1,014	594	385	16,189	8,614	3,475	Sept. 1
Malaria-----110-117	1	1	*	1	1	*	*	*	*	*
Measles-----085	6,261	7,076	6,650	6,261	7,076	6,650	42,308	45,148	43,319	Sept. 1
Meningitis, aseptic-----340 pt.	25	30	---	25	30	---	25	30	---	Jan. 1
Meningococcal infections-----057	37	36	34	37	36	34	691	696	890	Sept. 1
Poliomyelitis-----080	14	17	29	14	17	29	3,078	8,291	8,291	Apr. 1
Paralytic-----080.0,080.1	8	12	17	8	12	17	2,117	5,513	5,513	Apr. 1
Nonparalytic-----080.2	3	1	7	3	1	7	624	2,118	2,118	Apr. 1
Unspecified-----080.3	3	4	3	3	4	3	337	660	660	Apr. 1
Psittacosis-----096.2	1	1	*	1	1	*	*	*	*	*
Rabies in man-----094	-	-	*	-	-	*	*	*	*	*
Streptococcal sore throat, including scarlet fever-----050,051	7,596	6,977	---	7,596	6,977	---	105,248	---	---	Aug. 1
Typhoid fever-----040	6	6	13	6	6	13	692	732	1,023	Apr. 1
Typhus fever, endemic-----101	1	-	*	1	-	*	*	*	*	*
Rabies in animals-----------	42	67	86	42	67	86	612	1,051	1,035	Oct. 1

men who had had sex with men that later became known as acquired immunodeficiency syndrome (AIDS). Many other examples exist of first reports in *MMWR*. To name just a few examples: in 1970, *MMWR* reported on a nationwide epidemic of bacteremia associated with contaminated intravenous fluids (*7*); in 1976, on the occurrence of Guillain-Barré syndrome associated with the swine influenza vaccine (*8*); in 1977, on the discovery of the organism that causes Legionnaires disease (*9*); in 1991, on the effectiveness of folic acid for the prevention of spina bifida (*10*); in 1993, on an outbreak of hantavirus pulmonary syndrome (*11*); and two years ago, on the first two cases of 2009 pandemic influenza A (H1N1) (*12*). The traditional function of these first reports has been to fill the scientific information gap between immediate public health notifications through the news media and later publication of full-length articles in the peer-reviewed medical literature (*2*).

From 1961 to 1985, *MMWR* consisted only of the weekly publication, usually an eight- to 16-page booklet containing a few short narrative reports and the weekly morbidity and mortality tables, and the annual *Summary of Notifiable Diseases*. Since 1985, *MMWR* has evolved into the *MMWR* Series, a collection of six different products: 1) the *MMWR* weekly, 2) the annual *Summary of Notifiable Diseases*, 3) *CDC Surveillance Summaries*, 4) *Recommendations and Reports*, 5) special supplements, and 6) the *MMWR* weekly podcasts.

Although the general public best recognizes *MMWR* by the weekly report and the podcasts, the public health community relies heavily on the other components of the series. The *CDC Surveillance Summaries*, for example, a series of long-form reports and tables split off from the weekly in 1985 to publish the results of public health surveillance, often represent the only source of published surveillance statistics for certain topic areas. A few examples of recent reports include a report on the prevalence of autism spectrum disorders (*13*), an annual report on malaria surveillance (*14*), and a report on out-of-hospital cardiac arrests (*15*). The *Recommendations and Reports* series, split off from the *MMWR* weekly in 1990, consists of official recommendations from CDC. Many of these reports come from the Advisory Committee on Immunization Practices (ACIP) and present official recommendations for the use of childhood and adult vaccines. Recent examples of *Recommendations and Reports* topics include field triage of injured patients (*16*), guidelines for diagnosing and treating opportunistic infections in AIDS patients (*17,18*), and ACIP's guidelines for treatment and chemoprophylaxis of influenza (*19*). The *MMWR* podcast series began in 2006 and consists of two weekly podcasts: *A Cup of Health with CDC*, a 5- to 7-minute podcast, and *A Minute of Health with CDC*, a 59-second podcast.[†] Unlike the other five *MMWR* series, which are aimed at state and local health departments and other health professional audiences, the podcasts are aimed at a consumer audience.

Throughout its history one of *MMWR*'s core functions has been to report routine weekly surveillance statistics. Various forms of statistical tables on mortality and, beginning early in the 20th century, on morbidity, have appeared in *MMWR* since its inception as the *Bulletin* in 1878. For 39 years, the journal *Public Health Reports*, of which *MMWR* was then a part, carried the following motto above its surveillance tables: "No health department, State or local, can effectively prevent or control disease without knowledge of when, where, and under what conditions cases are occurring." By the time Langmuir brought *MMWR* to the Communicable Disease Center in 1961, he understood that surveillance data collected but never disseminated are of no use, and this understanding has remained part of *MMWR*'s central function (*20*).

The current *MMWR* weekly contains three morbidity and mortality tables plus a table published quarterly about tuberculosis. Table I lists provisional case counts for 40 infrequently reported nationally notifiable diseases (i.e., those for which <1,000 cases were reported during the preceding year). For

[†] See http://www.cdc.gov/mmwr/mmwrpodcasts.html.

example, for the week ending May 14, 2011, the 19th surveillance week for 2011, the table showed 19 cases of measles for the reporting week, 7 cases of noncholera *Vibrio* species infections, and five or fewer cases for all the other listed diseases. Table II lists provisional cases for >20 other selected nationally notifiable diseases for the current week, the median and maximum cases reported over the previous 52 weeks, and the cumulative (year-to-date) count of cases for the current and previous year. The diseases are listed by region and state, plus the District of Columbia, and five U.S. territories. During the 19th surveillance week of 2011, for example, Table II showed that 147 cases of giardiasis had been reported in the United States, including 23 from California, and that 19 cases of hepatitis A had been reported, including three from Georgia.

Table III is a mortality table for 122 U.S. cities. It lists the weekly number of deaths that occurred in the reporting jurisdiction by age group and has a separate column for deaths attributed to pneumonia and influenza. Since the earliest precursors of *MMWR*, mortality data for major U.S. cities based on death certificates have been reported directly to public health authorities and published in some form of this table. Table III is the nation's only national listing of weekly deaths. Detailed information about deaths by place of residence of the decedent eventually are validated and aggregated into a death file by CDC's National Center for Health Statistics, but the process can take up to 2 years. In a recent issue of *MMWR,* Table III showed that, during the week ending May 14, 2011, a total of 11,300 deaths were reported from the 122 cities. In Boston, for example, 133 deaths were reported, 86 of them in persons aged ≥65 years. Finally, Table IV reports provisional cases of tuberculosis for the current quarter, the minimum and maximum of the previous 4 quarters, the year to date, and the previous year's year to date in each U.S. region, state, and territory, as well as New York City and the District of Columbia.

In 1961, Langmuir made clear that *MMWR's* primary audience would be state and local health departments (*20*). Langmuir intended *MMWR* to be CDC's main method of mass communication with these departments and with the public health community. By the early 1980s, CDC was mailing *MMWR* free of cost to approximately 120,000 subscribers. In 1982, because of federal budget cuts, CDC was forced to reduce free circulation, but the gap was filled in 1983 by the *Journal of the American Medical Association* (JAMA), which began reprinting selected *MMWR* articles in its pages (*21*), a practice that continues today. In addition, beginning in 1983, the Massachusetts Medical Society began reprinting *MMWR* to paid subscribers (*22*),[§] another practice that continues today. *MMWR* began electronic circulation in 1995 (*23*), and over time, electronic subscription has increased to approximately 100,000. CDC still prints several thousand paper copies of *MMWR* and sends these free to state and local health departments, members of the news media, libraries, and a few other categories. Together with the circulation at the Massachusetts Medical Society and the U.S. government's Superintendent of Documents, the total print and electronic circulation of *MMWR* is now 134,000 as of September 2011; however, this number does not begin to capture *MMWR* readers in *JAMA* and other publications and approximately 1 million visitors to the *MMWR* website monthly. In addition, the *MMWR* podcasts are downloaded by about 50,000 listeners per week.

Langmuir knew that *MMWR* would be of great interest to the news media. Since the 1970s, CDC has given reporters access to *MMWR* articles the day before the articles are published. Today, reporters receive an advance copy of *MMWR* on Wednesday evenings, write their stories over Wednesday night, and then publish them after the *MMWR* media embargo ends at Thursday noon. For 5 decades, most health reports attributed to CDC in the news media likely have originated in *MMWR*. Even today, when viewers of evening television see something that "CDC reported today," often the *MMWR* logo is visible in the graphics. *MMWR* remains a main source of scientific information emanating from CDC, even though other channels, such as informal posting of information on the Web or releases given directly to news organizations, have begun to play a greater role.

Beginning in 2004, *MMWR* began releasing urgent reports outside the routine weekly *MMWR* issue. These reports, called "Early Releases" (formerly "Dispatches"), are sent immediately to electronic subscribers. *MMWR* uses Early Releases when the urgency of the public health problem cannot wait for the issuance of the weekly *MMWR* on Thursday noon. In 2010, CDC began a new monthly communication initiative called "CDC Vital Signs," which is anchored by a scientific report in *MMWR* (*24*).

MMWR and Medical Journals

Langmuir sometimes referred to his beloved *MMWR* as a "medical journal." In a 1979 interview, for example, Langmuir boasted that *MMWR*'s circulation of 84,000 qualified it as "one of the largest medical journals in the world" (*4*). However, *MMWR* has always carefully differentiated itself from medical journals. Even though some of the narrative articles in *MMWR* have the look and feel of articles in medical journals, *MMWR* remains distinct from medical journals—indeed from *all* other health-related publications.

The most obvious differences lie in the long-form *CDC Surveillance Summaries* and *Recommendations and Reports*

[§] For a time, *MMWR* also was reprinted by the Ochsner Clinic.

series. The *CDC Surveillance Summaries* represent the federal government and state health departments reporting official comprehensive surveillance statistics, a function not within the purview of medical journals. Similarly, *Recommendations and Reports* contains official federal public health recommendations, also outside the scope of most medical journals.

Several other differences exist. A major one is that, unlike medical journals (with a few exceptions, i.e., certain special supplements such as this one), the content published in *MMWR* constitutes the official voice of its parent, CDC. One sign of this is the absence in *MMWR* of any official disclaimers. Although most articles that appear in *MMWR* are not "peer-reviewed" in the way that submissions to medical journals are, to ensure that the content of *MMWR* comports with CDC policy, every submission to *MMWR* undergoes a rigorous multilevel clearance process before publication. This includes review by the CDC Director or designate, top scientific directors at all CDC organizational levels, and an exacting review by *MMWR* editors. Articles submitted to *MMWR* from non-CDC authors undergo the same kind of review by subject-matter experts within CDC. By the time a report appears in *MMWR*, it reflects, or is consistent with, CDC policy.

For decades, articles in the *MMWR* weekly written by CDC scientists bore attribution only to the CDC program in which the scientist worked (state or local health department authors were always attributed by name). The intent was to convey to readers that the author of the article was actually CDC as an institution, not the individual contributors. In 2002, the *MMWR* weekly began allowing attribution to individual CDC contributors by name, but even today, reports in the weekly still are attributed to CDC officially as an institution and appear as authored by CDC in the National Library of Medicine's MEDLINE database.

Another identifying characteristic of *MMWR* is its unique format. In its early years, *MMWR* established its trademark short rapid report format for breaking public health problems. In a 1984 memorandum, an *MMWR* editor described the publication's style as having "few adjectives and verbs." During the same year, an observer described *MMWR's* style as "brisk and businesslike, redolent of competence and devoid of levity…. A crisp, lucid, oddly vivid style suggestive of Hemingway as retold by Strunk and White" (*25*). Although a few reports in today's *MMWR* are perhaps more ornate than those of previous decades, the publication still works hard to retain its short form and almost quirky devotion to careful, precise Spartan language.

Yet another difference between *MMWR* and most medical journals is its absence of correspondence from readers, advertising, advocacy, and opinion. Most medical journals are part of a conversation with their readers through publication of letters to the editor and responses from authors. *MMWR* has always accepted letters (now e-mails) from readers and has forwarded these to authors for individual response but has never published correspondence and has left the forums for public health discussion to other publications.[¶] *MMWR* contains no advertising or promotional materials, even on behalf of CDC, or any advocacy or self-promotion for CDC or for particular public health programs. Although since the late 1960s *MMWR* has published an "editorial note" for most articles appearing in the weekly (little known fact: these are written by the contributors or the CDC subject-matter experts, not by the *MMWR* editor), in keeping with its status as the official voice of CDC, *MMWR* has never published "opinion" per se. Comments in editorial notes all are in accordance with CDC policy, and no individual opinion appears.

MMWR's continued adherence to an unadorned matter-of-fact style might be part of the reason it has maintained a high level of credibility among its readers. In a survey conducted by Mercer Management Consulting during 2005–2006 among >11,000 subscribers, *MMWR*'s score on credibility was 4.76 of 5.00 (1 = poor, 5 = excellent). In the same survey, *MMWR* scored an average respondent score of 4.60 of 5.00 on quality of content, 4.52 on usefulness, 4.49 on timeliness, and 4.40 on readability. Of 18 publications tested, no publication outscored *MMWR* on credibility, usefulness, or quality of content. Besides its simple style and lack of advertising, another reason for these high reader marks likely is *MMWR*'s association with CDC.

MMWR in the Future

When public health threats arise, one of *MMWR*'s most important traditional functions has been to provide crucial scientific information during that time between the immediate notification to the public about the threat and the later definitive scientific description of the event in a medical journal (*2*). This important "filling the gap" function has remained a main part of *MMWR*'s mission. As a classic example, on February 1, 2008, *MMWR* published an Early Release report about acute allergic-type reactions among patients undergoing hemodialysis in multiple states (*26*). The authors said the temporal and geographic distribution of these reactions suggested common exposure to a widely distributed health-care product. They named heparin as a possible culprit and asked readers to send reports to their local or state health department. By February 11, heparin had been identified as the most likely culprit, and the manufacturer had halted production. A definitive scientific

[¶] In 2010, *MMWR* established a Facebook page on which readers can comment on *MMWR* articles; so far, this page has been used almost entirely by lay readers rather than by *MMWR*'s scientific audience.

description of the incident appeared in the *New England Journal of Medicine* on June 5, 2008 (*27*).

In the Internet age, the information gap between immediate announcement of public health events by the news media and publication in medical journals is narrowing. *MMWR*'s "filling the gap" function can be done now in several ways. During the recent pandemic of 2009 influenza A (H1N1), CDC programs relied heavily on publication in *MMWR*, and 45 reports on the pandemic appeared in its pages through the end of 2010. However, to an unprecedented degree, CDC also relied on informal postings on the Web and direct releases to the media to convey a large amount of scientific information to health departments and the public. In addition, medical journals were much quicker about publishing fresh results. Soon after the outbreak was recognized, the *New England Journal of Medicine* published information about the epidemiology of the newly characterized disease within just a few days after data collection (*28*). Many other publications posted electronic journal articles within just days of submission. In addition, other informal methods of communication have come to the fore (e.g., *PLoS Currents*).

In the last few years, the Internet has revolutionized medical publishing. Old medical journals are now questioning their business models, especially models that rely on printing on paper. The extent to which this publishing maelstrom will affect *MMWR* is uncertain. Certainly, some of the scientific functions of *MMWR* cannot be supplanted by informal posting on the Web. *CDC Surveillance Summaries* and vaccine recommendations must maintain a minimum level of formality to be considered credible and generally that includes formal indexing in MEDLINE, a step that makes them part of the medical literature. That need suggests they will be published in *MMWR* for a long time to come, but even that is uncertain. Already, some traditional *MMWR* contributors, faced with pressure to publish material more quickly and less expensively, have elected to simply post materials on the Web rather than submit them for formal editing, publication, and indexing.

Over the past 50 years, *MMWR* has changed as CDC's mission has changed and as successive generations of *MMWR* authors, editors and staff members have carried it forward. One tribute to *MMWR*'s continued vitality is the growing desire of many other nations to have their own *MMWR*-like publications, and *MMWR* editors often give advice on this to foreign ministries of health. Many people—readers, staff members, and friends—have come to love the little publication that has done so much for public health over so long, and they now worry about its fate in the modern-day publishing maelstrom. Perhaps all should recall the many times in the past 50 years when upheavals in public health, technology, and publishing seemed to spell trouble for *MMWR*, but through it all, *MMWR* adapted, persevered, and flourished.

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A History of *MMWR*

Frederic E. Shaw, MD, JD[1]
Richard A. Goodman, MD, JD[2]
Mary Lou Lindegren, MD[3]
John W. Ward, MD[4]

[1]*Public Health Surveillance Program Office, Office of Surveillance, Epidemiology and Laboratory Services, CDC, Atlanta, Georgia*
[2]*National Center for Chronic Disease Prevention and Health Promotion, CDC, Atlanta, Georgia*
[3]*Department of Pediatrics, Vanderbilt University School of Medicine, Nashville, Tennessee*
[4]*Division of Viral Hepatitis, National Center for HIV/AIDS, Viral Hepatitis, STD, and TB Prevention, CDC, Atlanta, Georgia*

Corresponding author: Frederic E. Shaw, MD, JD, Public Health Surveillance Program Office, Office of Epidemiology, Surveillance and Laboratory Services, CDC, Mailstop E-97, 1600 Clifton Road, N.E., Atlanta, GA 30333;Telephone: 404-498-6364; Fax: 404-498-0585; E-mail: fxs6@cdc.gov.

MMWR was established to disseminate the results of public health surveillance and owes much of its existence to the founder of modern surveillance, William Farr (1807–1883). In 1878, under the sway of Farr, Lemuel Shattuck, and other pioneers of surveillance, the U.S. government created the first precursor of *MMWR* and entered the business of publishing surveillance statistics. Farr's influence touched *MMWR* again in 1961 when one of his adherents, Alexander D. Langmuir (Figure 1), brought *MMWR* to Atlanta and CDC from a federal office in Washington, D.C. (*1*). Since its beginnings, *MMWR* has played a unique role in addressing emerging public health problems by working with state and local health departments to announce problems even before their cause is known, rapidly disseminating new knowledge about them weeks or months before articles appear in the medical literature, and publishing recommendations for their control and prevention. *MMWR* has played this role time after time—the discovery of Legionnaires disease in the 1970s, AIDS and toxic-shock syndrome in the 1980s, hantavirus pulmonary syndrome in the 1990s, and severe acute respiratory syndrome (SARS) in the 2000s. At the same time, *MMWR* also has reported on nearly all the major noninfectious public health problems of the day—environmental emergencies, chronic diseases, injuries, and new public health technologies. To a great extent, the history of *MMWR* is the history of disease and injury prevention and control in the United States (Table 1).

MMWR's Precursors

MMWR's history began on April 29, 1878, when Congress passed the National Quarantine Act. The Act required the Surgeon General of the U.S. Marine-Hospital Service (later to become the U.S. Public Health Service [PHS]) to collect reports from U.S. consular officers on the sanitary condition of vessels departing for the United States and to give notice of these vessels to federal and state officers through weekly abstracts (*2*). This mandate resulted in *The Bulletin of the Public Health* (Figure 2), the first precursor of *MMWR*. The Marine-Hospital Service published the first issue of the *Bulletin* on July 13, 1878. It ran just six paragraphs and described cases of cholera, smallpox, and yellow fever in Key West, Florida; Cuba; and Malta (*3*). In 1878, a great yellow fever epidemic was raging in the Mississippi Valley, eventually to claim 20,000 lives (*4*), and a reader of these early reports can feel its deadly effects. On August 24, 1878, the *Bulletin* published a telegram from Dr. Booth, the Marine-Hospital Service officer at Vicksburg, Mississippi: "I am sick; impossible to procure accurate data." A week later, the *Bulletin's* report from Vicksburg said, "Dr. Booth, in charge of the patients of the Marine-Hospital Service, died the 27th."

On June 2, 1879, Congress repealed the earlier reporting provisions, and the *Bulletin* ended after just 46 issues, leaving dormant the reporting of surveillance statistics by the federal government. It reawakened with the advent of a new publication in 1887, *The Weekly Abstract of Sanitary Reports*, which continued the numbering of the *Bulletin*. Issue number 47 appeared on January 20, 1887. Like the *Bulletin*, the new publication contained communicable disease reports from foreign ports and the U.S. states, including a mortality table of U.S. cities. The *Weekly Abstract* also contained occasional narrative reports on public health topics. It reached 1,800 readers and was, in its editor's words, "greatly appreciated not only by quarantine officers, but steamship companies, merchants, and the press" (*4*).

On January 3, 1896, *The Weekly Abstract* became *Public Health Reports*, a journal that is still published today as the official journal of PHS. Initially, *Public Health Reports* looked a great deal like the *Weekly Abstract*, but in time *Public Health Reports* took the form of a full-fledged scientific journal and published important observations and research on communicable diseases and epidemiologic and laboratory investigations, plus such items as municipal ordinances, state legislation, and public health legal opinions. The PHS published *Public Health Reports* weekly until 1952, when it became a monthly publication, and in 1974, a bimonthly. By 1913, a motto of public

FIGURE 1. Alexander D. Langmuir, circa 1965

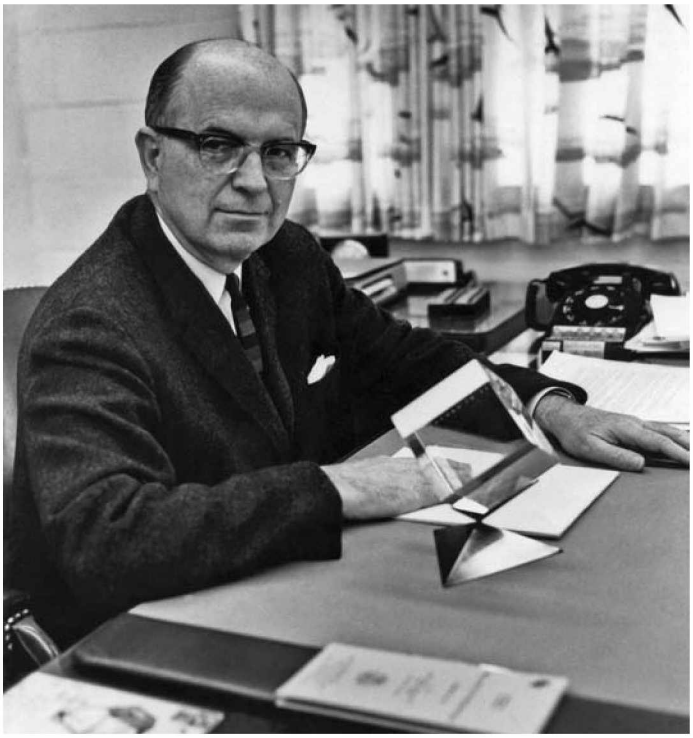


Photo: CDC

health surveillance principles was appearing on the masthead of the publication's pages reporting notifiable diseases: "No health department, State or local, can effectively prevent or control disease without knowledge of when, where, and under what conditions cases are occurring." This motto appeared in *Public Health Reports* for 39 years (*5*).

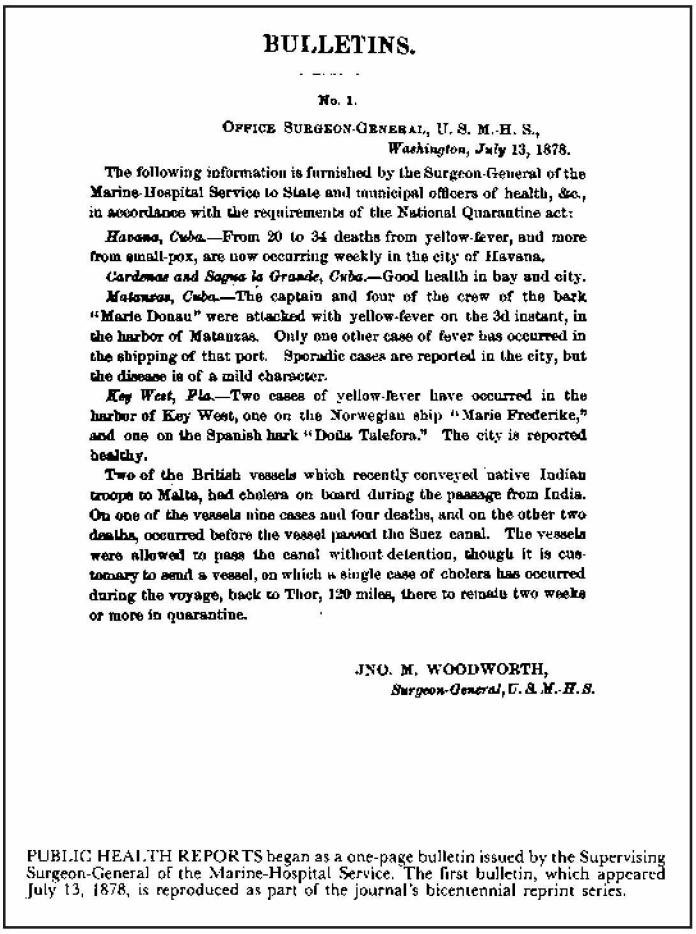
Until 1942, morbidity statistics were collected, compiled, and published in *Public Health Reports* by the PHS Division of Sanitary Reports and Statistics. In that year, this responsibility was transferred to the Division of Public Health Methods, and in 1949, to the National Office of Vital Statistics (NOVS),* another PHS agency (*5*). Morbidity and mortality statistics continued to be published in *Public Health Reports* until January 20, 1950, when they were transferred to a new NOVS publication called the *Weekly Morbidity Report*, the first publication to look like the modern-day *MMWR*. In 1952, NOVS changed the name of this publication to the *Morbidity and Mortality Weekly Report*.

*NOVS was merged with the National Health Survey in 1960 to form the National Center for Health Statistics, which became part of CDC in 1987.

TABLE 1. Timeline of major events in *MMWR* history, 1878–2011

Year	Major Event
1878	First issue of *The Bulletin of the Public Health*, the first ancestor of *MMWR*, is published. It ceases publication after just 46 weekly issues.
1887	The first *Weekly Abstract of the Sanitary Reports* is published.
1896	*The Weekly Abstract of Sanitary Reports* becomes *Public Health Reports*, the official journal of the U.S. Public Health Service published today by the Association of Schools of Public Health.
1950	Dissemination of federal morbidity and mortality statistics is transferred from *Public Health Reports* to the *Weekly Morbidity Report*, a new publication of the federal National Office of Vital Statistics (NOVS).
1952	NOVS changes the name of the *Weekly Morbidity Report to* the *Morbidity and Mortality Weekly Report (MMWR)*.
1960	The Department of Health, Education and Welfare transfers responsibility for publishing the *MMWR* to the Communicable Disease Center (CDC).
1961	CDC publishes its first issue of *MMWR*.
1967	CDC's name is changed to the National Communicable Disease Center.
1970	CDC's name is changed to the Center for Disease Control.
1977	In January 1977, *MMWR* publishes its first and only special edition until 2002. It describes the discovery of the organism that causes Legionnaires disease.
1980	CDC's name is changed to the Centers for Disease Control.
1981	In *MMWR*, CDC publishes reports of the first five cases of AIDS.
1981	*MMWR* articles are for the first time included in Index Medicus.
1982	*MMWR* subscribers are reduced from approximately 120,000 to 12,000 because of federal budget cuts. The Massachusetts Medical Society begins print subscriptions for *MMWR*. The *Journal of the American Medical Association* reprints *MMWR* articles. Both arrangements continue today.
1983	*CDC Surveillance Summaries*, a new series of *MMWR*, is published for the first time.
1990	*Recommendations and Reports*, a new series of *MMWR*, is published for the first time.
1992	CDC's name is changed to the Centers for Disease Control and Prevention.
1992	*MMWR* content becomes available on an FTP server on the Internet.
1995	*MMWR* content becomes available on the World-Wide Web.
2001	*MMWR* format changes from 6-inch by 8-inch, one-color format to 8½ inch by 11 inch, two-color format.
2002	*MMWR* establishes ability to publish Dispatches, online reports that can be distributed by email day or night. The first Dispatch is published in September 2002.
2006	The *MMWR* Editorial Board is established and holds its first meeting.
2006	*MMWR* weekly podcast series is established. The podcasts are *MMWR*'s first product for lay audiences.
2009	*MMWR*'s first Deputy Editor is appointed. A second Deputy Editor is appointed in 2010.
2010	*MMWR* establishes a presence on social media (Facebook and Twitter).

FIGURE 2. *The Bulletin of the Public Health*, published by the U.S. Marine-Hospital Service, July 13, 1878



BULLETINS.

No. 1.

OFFICE SURGEON-GENERAL, U. S. M.-H. S.,
Washington, July 13, 1878.

The following information is furnished by the Surgeon-General of the Marine-Hospital Service to State and municipal officers of health, &c., in accordance with the requirements of the National Quarantine act:

Havana, Cuba.—From 20 to 34 deaths from yellow-fever, and more from small-pox, are now occurring weekly in the city of Havana.

Cardenas and Sagua la Grande, Cuba.—Good health in bay and city.

Matanzas, Cuba.—The captain and four of the crew of the bark "Marie Donau" were attacked with yellow-fever on the 3d instant, in the harbor of Matanzas. Only one other case of fever has occurred in the shipping of that port. Sporadic cases are reported in the city, but the disease is of a mild character.

Key West, Fla.—Two cases of yellow-fever have occurred in the harbor of Key West, one on the Norwegian ship "Marie Frederike," and one on the Spanish bark "Dolla Talefora." The city is reported healthy.

Two of the British vessels which recently conveyed native Indian troops to Malta, had cholera on board during the passage from India. On one of the vessels nine cases and four deaths, and on the other two deaths, occurred before the vessel passed the Suez canal. The vessels were allowed to pass the canal without detention, though it is customary to send a vessel, on which a single case of cholera has occurred during the voyage, back to Thor, 120 miles, there to remain two weeks or more in quarantine.

JNO. M. WOODWORTH,
Surgeon-General, U. S. M.-H. S.

PUBLIC HEALTH REPORTS began as a one-page bulletin issued by the Supervising Surgeon-General of the Marine-Hospital Service. The first bulletin, which appeared July 13, 1878, is reproduced as part of the journal's bicentennial reprint series.

Bringing *MMWR* to CDC

In 1960, CDC was only 14 years old; it had been organized in 1946 in Atlanta as an outgrowth of the federal agency, Malaria Control in War Areas (*6*). In 1949, Langmuir came to CDC, then known as the Communicable Disease Center, to head the epidemiology branch. Early in his career, Langmuir had worked at local and state health departments and had recognized the crucial importance of vital statistics and public health surveillance. During his early years at CDC, he noticed that the staff at NOVS who received, compiled, and reported federal surveillance statistics were not trained in epidemiology and, as a colleague later said, "had no obligation—or, apparently, inclination—to analyze data rapidly and act on the implications" (*7*). Langmuir became determined to move the surveillance function and its accompanying publication, *MMWR*, to CDC's epidemiology branch.

To counteract ambivalence about the transfer at both NOVS and CDC (*7;* David J. Sencer, personal communication, August 10, 2010), Langmuir worked hard to persuade his superiors that the job of disease surveillance fit better into CDC's mission than NOVS's. He enlisted help from colleagues in Washington and at CDC. David J. Sencer, the future director of CDC who was then working at the Bureau of State Services in Washington, weighed in on Langmuir's side, as did the Surgeon General's Study Group and a task force that had been appointed to consider the transfer. As Langmuir later said in an interview, "[After] all sorts of pulling out teeth by the roots without anesthesia and all kinds of internal frictions, … on July 1st, 1960, we had the obligation, formal duty, of issuing the weekly morbidity and mortality report" (*8*). The Department of Health, Education, and Welfare formally approved the transfer on September 30, 1960. To make *MMWR* functional at CDC, the Department transferred a budget of $16,500 and 1.5 employee positions to CDC (David J. Sencer, personal communication, August 10, 2010).

Langmuir named E. Russell Alexander as the first CDC editor of *MMWR* but worked tirelessly on *MMWR* himself (Table 2). During *MMWR*'s first 9 years at CDC, Langmuir gave *MMWR* his highest priority, labored over the text of each article, and approved gradual improvements. Over time, Langmuir began using *MMWR* to change practices in state and local health departments and clinicians (*8*). To make state and local health departments' work more prominent, he required that authors of *MMWR* articles from state and local health departments be listed first and that CDC authors be listed only by the name of their program and not individually. Langmuir also experimented with the use of an editorial note to accompany the factual reports.

The 1970s and 1980s

A turning point in the history of *MMWR* was Langmuir's appointment of Michael B. Gregg as *MMWR* editor in 1967 (Figure 3). Gregg became the longest-serving editor in *MMWR*'s history and exerted a major effect on *MMWR*'s personality, language, and scientific standards. Gregg had come to CDC in 1966 and had worked under Langmuir (*9,10*). Soon after Langmuir appointed him as *MMWR* Editor, Gregg applied his literary skills to *MMWR*, editing each article carefully to ensure that it was written in clear, compact English and that it stuck to the epidemiologic findings (*11*; Anne Mather, personal communication, August 17, 2010).† During the 1970s, Gregg developed the editorial note into a

† Gregg later wrote, "The *MMWR* is not a compilation of unsubstantiated information gathered by a variety of lay, semi-scientific or even scientific sources to alarm, persuade, or otherwise convince the reader by subtle editorialization, but rather the reports comprise the best available scientific data obtained by professionals, carefully reviewed and articulated, shorn of modifiers, primarily designed to bridge the gap between the traditional news media reports of events on the one hand, and the 6–12 month to even 18-month delay before the bloom of scientific publication on the other" (*5*).

TABLE 2. *MMWR* Editors, Managing Editors, and Deputy Editors, 1961–2011

Years	Editor
1961–1962	E. Russell Alexander
1962–1963	P.R. Joseph
1963–1964	Lawrence K. Altman
1965–1966	D.J.M. MacKenzie
1967–1988	Michael B. Gregg
1988–1998	Richard A. Goodman
1998–2005	John W. Ward
2005–2006	Mary Lou Lindegren
2007–2010	Frederic E. Shaw
2010–	Ronald L. Moolenaar
	Managing Editor
1954–1965	P.D. Stolley
1968–1970	Priscilla B. Holman
1971–1972	Susan J. Dillon
1973–1974	Deborah L. Jones
1975	Katherine A. Sherman
1975–1981	Anne Mather
1982–1986	Karen L. Foster
1987-1988	Gwendolyn A. Ingraham
1988–2000	Karen L. Foster
2000	Caran R. Wilbanks (Acting)
2000–2002	Teresa F. Rutledge (Acting)
2002–2003	David C. Johnson (Acting)
2003–2008	Suzanne M. Hewitt
2008–	Teresa F. Rutledge
	Deputy Editor
2009–	Christine G. Casey
2010–	John S. Moran

consistent and valuable feature of each article; he took special pride in these notes, which he observed were the most-read part of *MMWR* articles and gave CDC a chance to point out the implications of the facts presented (*11*). The editorial note became the place where each *MMWR* report answers the "so what?" question: what actions should be taken by readers (e.g., medical personnel, state and local health departments) as a result of the information in the report.

One of Gregg's most enduring contributions to *MMWR* was to persuade the National Library of Medicine to include content from *MMWR* in the Index Medicus (*10*). Beginning in 1981, inclusion there would mean that all reports published in *MMWR* would forever become part of the indexed medical literature. Through Gregg's steady improvements, gradually *MMWR* became required reading at state and local health departments and medical offices and within the health press.

In early May 1981, Gregg received a telephone call from Wayne Shandera, an Epidemic Intelligence Service (EIS) Officer assigned to the Los Angeles County Department of Health (*12*). Shandera described five cases of *Pneumocystis carinii* pneumonia in young men. The five men had in common that they were previously healthy and had had sex with other men. *Pneumocystis* pneumonia was seen mainly in persons with

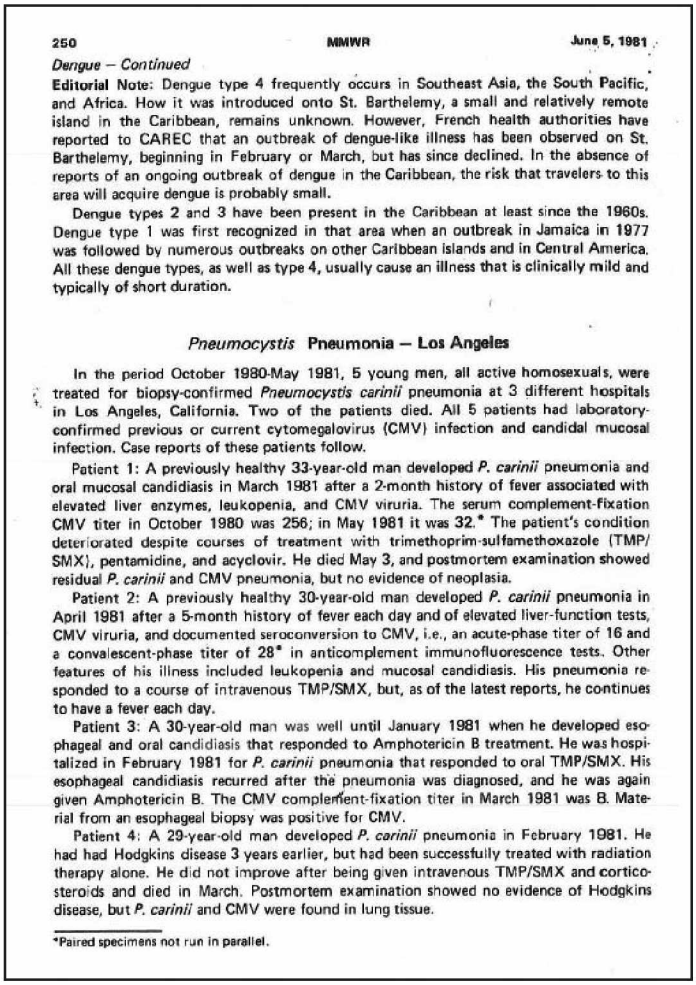
FIGURE 3. Michael B. Gregg, circa 1968

Photo: CDC

cancer or other immunosuppressive conditions, and a group of five cases in otherwise healthy young men was highly unusual. The attending physician who had treated four of the men, Michael Gottlieb, wanted to publish the cases in a medical journal but knew that would take months (*6*). Shandera asked Gregg whether he would be interested in publishing a description of the cases in *MMWR*. Gregg did not know quite what to make of the cases but asked Shandera to submit a report to MMWR (*12*). After consulting with colleagues at CDC, Gregg published the report in *MMWR* on June 5, 1981 (*13*) (Figure 4). Immediately after the article appeared, clinicians across the country who had seen similar patients realized the connection to the Los Angeles cases (*12*). Recognition of the AIDS epidemic had begun. The first AIDS article in the peer-reviewed medical literature appeared 4 months later (*14*).

Until the mid-1980s, CDC provided a free print subscription by airmail to anybody who requested one, and circulation rocketed from approximately 6,000 in 1961 to 80,000 in 1981 and 120,000 in 1983. In 1982, the cost of *MMWR* printing

FIGURE 4. First page of the first AIDS report, June 5, 1981



250 MMWR June 5, 1981

Dengue – Continued

Editorial Note: Dengue type 4 frequently occurs in Southeast Asia, the South Pacific, and Africa. How it was introduced onto St. Barthelemy, a small and relatively remote island in the Caribbean, remains unknown. However, French health authorities have reported to CAREC that an outbreak of dengue-like illness has been observed on St. Barthelemy, beginning in February or March, but has since declined. In the absence of reports of an ongoing outbreak of dengue in the Caribbean, the risk that travelers to this area will acquire dengue is probably small.

Dengue types 2 and 3 have been present in the Caribbean at least since the 1960s. Dengue type 1 was first recognized in that area when an outbreak in Jamaica in 1977 was followed by numerous outbreaks on other Caribbean islands and in Central America. All these dengue types, as well as type 4, usually cause an illness that is clinically mild and typically of short duration.

***Pneumocystis* Pneumonia – Los Angeles**

In the period October 1980-May 1981, 5 young men, all active homosexuals, were treated for biopsy-confirmed *Pneumocystis carinii* pneumonia at 3 different hospitals in Los Angeles, California. Two of the patients died. All 5 patients had laboratory-confirmed previous or current cytomegalovirus (CMV) infection and candidal mucosal infection. Case reports of these patients follow.

Patient 1: A previously healthy 33-year-old man developed *P. carinii* pneumonia and oral mucosal candidiasis in March 1981 after a 2-month history of fever associated with elevated liver enzymes, leukopenia, and CMV viruria. The serum complement-fixation CMV titer in October 1980 was 256; in May 1981 it was 32.* The patient's condition deteriorated despite courses of treatment with trimethoprim-sulfamethoxazole (TMP/SMX), pentamidine, and acyclovir. He died May 3, and postmortem examination showed residual *P. carinii* and CMV pneumonia, but no evidence of neoplasia.

Patient 2: A previously healthy 30-year-old man developed *P. carinii* pneumonia in April 1981 after a 5-month history of fever each day and of elevated liver-function tests, CMV viruria, and documented seroconversion to CMV, i.e., an acute-phase titer of 16 and a convalescent-phase titer of 28* in anticomplement immunofluorescence tests. Other features of his illness included leukopenia and mucosal candidiasis. His pneumonia responded to a course of intravenous TMP/SMX, but, as of the latest reports, he continues to have a fever each day.

Patient 3: A 30-year-old man was well until January 1981 when he developed esophageal and oral candidiasis that responded to Amphotericin B treatment. He was hospitalized in February 1981 for *P. carinii* pneumonia that responded to oral TMP/SMX. His esophageal candidiasis recurred after the pneumonia was diagnosed, and he was again given Amphotericin B. The CMV complement-fixation titer in March 1981 was 8. Material from an esophageal biopsy was positive for CMV.

Patient 4: A 29-year-old man developed *P. carinii* pneumonia in February 1981. He had had Hodgkins disease 3 years earlier, but had been successfully treated with radiation therapy alone. He did not improve after being given intravenous TMP/SMX and corticosteroids and died in March. Postmortem examination showed no evidence of Hodgkins disease, but *P. carinii* and CMV were found in lung tissue.

*Paired specimens not run in parallel.

and distribution came under scrutiny, and CDC director William Foege was obliged to take "a painful departure from our tradition" (*15*) and notify *MMWR* readers that CDC would no longer provide unrestricted free distribution. Overnight, free mailed subscriptions from CDC dropped from 120,000 to about 12,000. The drastic reduction in free distribution prompted complaints from subscribers and the medical community. Foege, Gregg, and colleagues at CDC talked with leaders in the medical press about how to fill the gap. On February 24, 1983, the editor of the *New England Journal of Medicine*, Arnold S. Relman, announced that the *Journal*'s parent organization, the Massachusetts Medical Society, would begin reprinting *MMWR* and selling subscriptions at $20.00 per year (*16*). That arrangement, at a current rate of $189 per year, remains in effect, and the Society continues to reprint all series of *MMWR* for approximately 5,500 paid subscribers (Ann Russ, Massachusetts Medical Society, personal communication, September 7, 2010). In March 1983, George D. Lundberg, the editor of the *Journal of the American Medical Association* (JAMA), announced that *JAMA* would begin publishing weekly in its pages lead articles from *MMWR* (*17*). That arrangement, too, continues today.[§]

The 1990s

Gregg stepped down as *MMWR* editor in 1988 and was succeeded by Richard A. Goodman. During Goodman's tenure as editor, two of *MMWR's* priorities were to expand its content and turn the articles toward specific public health actions. By 1990, *MMWR*'s circulation had rebounded to 45,000–50,000 (*7*), mostly through the Massachusetts Medical Society. The national news media were covering CDC's activities closely, and several times each month *MMWR* articles were the source of national news stories. By the early 1990s, *MMWR* had published hundreds of articles on the burgeoning AIDS epidemic. One of the most influential was an article published July 27, 1990, about transmission of HIV to patients by a dentist in Florida (*18*), the first documented instance of HIV transmission through a medical procedure. Publication of this report received enormous attention by the media, dramatically underscoring the sway of CDC and *MMWR* over public health information (Richard A. Goodman, personal communication, August 18, 2010).

By 1990, *MMWR* had become a series of four publications: the *MMWR* weekly, the annual *Summary of Notifiable Diseases*, the *CDC Surveillance Summaries*, and Supplements. The *Surveillance Summaries* series had been created in 1983 by Stephen B. Thacker, the director of the CDC surveillance office from which the *MMWR* emanated, to centralize and promote surveillance activities of CDC programs (Stephen B. Thacker, personal communication, August 17, 2010). Previously, CDC surveillance data had been published and distributed by each individual CDC program. The rising prominence of *MMWR* placed more pressure on authors inside and outside CDC to publish their findings quickly in *MMWR*. EIS Officers had a new requirement to submit reports to *MMWR* as part of their CDC training. Submissions to *MMWR* soared.

In the late 1980s, *MMWR* determined that just one type of report consumed approximately one fourth of all text pages in the *MMWR* weekly: official vaccination recommendations from CDC's Advisory Committee on Immunization Practices (*19*; Richard A. Goodman, personal communication, August 18, 2010). To alleviate the problem and to accommodate demand for space for reports of epidemiologic field investigations and other work, *MMWR* created the *Recommendations and Reports* in 1990. Since then, the *Recommendations and Reports* series has been *MMWR's* main vehicle for publishing the full spectrum of official CDC recommendations, from the

[§] For a time, the Ochsner Clinic also reprinted *MMWR*.

diagnosis of tuberculosis to the vaccination recommendations of the Advisory Committee on Immunization Practices.

The 1990s also marked *MMWR's* first foray into electronic publishing. Since the mid-1980s, CDC had made *MMWR* available to state and local health departments and other entities through dedicated electronic systems operated through telephone lines (*20*). In 1992, *MMWR* content became available through a file transfer protocol (FTP) server. However, these systems were often expensive and difficult to use. Beginning in 1993, CDC began to convert *MMWR* into electronic format and increase its availability through the Internet. In January 1995, the publication made its editions available both through FTP and the World-Wide Web (*21*; T. Demetri Vacalis, personal communication, August 11, 2010). The new Internet distribution quickly had an unanticipated benefit. In 1995, *MMWR* had never missed publishing a weekly issue (a record that remains true today). In November of that year, 10 months after *MMWR* instituted electronic distribution, the federal government shut down all but emergency functions because of a budget impasse between the President and the Congress. For its November 17, 1995, edition, *MMWR* had to delay printing the weekly issue, but still released *MMWR* on time through its new electronic capability (*22*).

In June 1996, on the occasion of CDC's 50th anniversary, *MMWR* published a special issue featuring CDC's history and the evolution of reporting public health data (*23*). In 1999, also in recognition of CDC's 50th anniversary, *MMWR* published a compendium of selected reports that had appeared during 1961–1996 on such topics as smallpox, Legionnaires disease, HIV/AIDS, and other major public health events covered in *MMWR* (*24*).

The 2000s

The events of September 11, 2001, and the subsequent anthrax attacks brought a major focus on bioterrorism and emergency preparedness to CDC and *MMWR*. During the 2000s, other public health events also affected the path of *MMWR*, including the advent of SARS, the expansion of West Nile and emergence of monkeypox virus infections in the United States, and greater national aspirations for the control of influenza epidemics. At the same time, *MMWR* was obliged to cope with a building maelstrom in the medical publishing world spawned by the explosive growth of the Internet.

Goodman stepped down as editor in 1998 and was succeeded by John W. Ward. One of Ward's first jobs was to find a way for *MMWR* to celebrate the coming new millennium. Jeffrey P. Koplan, CDC director during 1998–2002, came up with the idea of a series on the 10 great achievement of public health in the previous century. *MMWR* began publishing the series in April 1999 (*25*), and the articles became among the most cited ever published by *MMWR*.

The new millennium was only months old when the attacks of September 11 occurred, followed in October by the intentional releases of anthrax spores. *MMWR* published its first article on the anthrax attacks on October 12, 2001 (*26,27*), and for weeks published updates on the epidemiologic investigation and recommendations. In March 2003, when SARS erupted around the world, *MMWR* began to publish articles on the epidemic, updating the number of cases reported to the World Health Organization, the number of deaths and related public health alerts and information (*28*).

By 2002, most *MMWR* subscribers received the publication by e-mail, which had supplanted postal letters as the main method of communication between CDC and state and local health departments. *MMWR*'s e-mail circulation was approximately 30,000, which when combined with the ongoing print subscriptions mailed by CDC and the Massachusetts Medical Society, gave a total circulation of about 50,000.[¶] The occurrence of so many public health emergencies during the early 2000s brought the realization that, during critical events, *MMWR* could no longer wait until the routine weekly issue on Friday to send critical information to readers (John W. Ward, personal communication, August 4, 2010.). Before 2002, only once in its history had *MMWR* published an issue on a day other than Friday, in January 1977 to announce CDC's discovery of the bacterium that caused Legionnaires disease (David J. Sencer, personal communication, August 10, 2010). On September 13, 2002, *MMWR* published its first "Dispatch," a new form of urgent report that could be emailed to readers at any time, day or night (*29*).

The early 2000s brought other changes as *MMWR* strove to adapt to the rapidly changing communications world (Mary Lou Lindegren, personal communication, August 9, 2010). The *MMWR* series became more Web-centric, adapting its editorial policies to match Web-based publication. In 2001, *MMWR*'s graphical appearance changed from its longstanding 6- by 8-inch black-and-white format to a new 8½-inch by 11-inch two-color format. To match the scope of CDC's work, *MMWR's* content became more diverse (e.g., reviews by CDC's *Guide to Community Health Services*, more reports on chronic disease and injuries, and a new one-page graphical snapshot of key public health statistics called QuickStats, produced by CDC's National Center for Health Statistics). In 2002, CDC contributors to the weekly were for the first time listed by name.

[¶] The circulation of *MMWR* through the Massachusetts Medical Society in 2002 was 13,500 (*19*).

Ward stepped down as the MMWR editor in 2005 and was succeeded by Mary Lou Lindegren. In 2005, both Ward and Lindegren believed that MMWR needed an advisory board to provide independent advice to the *MMWR* editor. After 2 years of planning, the *MMWR* Editorial Board met for the first time in June 2006, chaired by William L. Roper, a former CDC director. Also during the mid-2000s, in response to findings from a CDC committee on the quality of evidence used in CDC recommendations, for the first time *MMWR* listed explicit guidelines for making official recommendations in its pages and required contributors to state more clearly the evidentiary basis of recommendations. *MMWR* also revamped its production process; added new technologies such as RSS feeds; and developed new content, such as a series of perspective reports from past CDC directors and a compendium celebrating 60 years of public health science at CDC (*30*). *MMWR* also increased its role in documenting the impact of global public health initiatives (e.g., polio eradication, measles eradication, global HIV control efforts), and copublished many articles with the World Health Organization's *Weekly Epidemiological Record*.

Lindegren was succeeded by Frederic E. Shaw in 2007 and *MMWR* added its first deputy editor in 2009.** Beginning October 2006, two new podcasts, broadcast in English and Spanish, became the sixth component of the *MMWR* series. They were *MMWR*'s first foray into products for lay audiences. *MMWR* also revamped the graphical format of the series (the first revision since 2001), added new report types to the weekly (e.g., CDC's Public Health Grand Rounds, mini-articles that appear under the header, "Notes from the Field"), and instituted an *MMWR* presence on Facebook and Twitter. In 2010, *MMWR* also implemented a suggestion from CDC's new director, Thomas R. Frieden, by inaugurating the publication of "Vital Signs," a new coordinated CDC communication effort anchored by scientific articles in *MMWR* (*31*). In April 2009, the worldwide outbreak of pandemic influenza A (H1N1) (then called swine influenza H1N1) began; *MMWR* reported the first two cases on April 21, 2009 (*32*), then published rapid-fire articles on the pandemic, including *MMWR*'s first published articles in Spanish. By the end of 2010, *MMWR* had published 45 articles on various aspects of the pandemic.

By 2007, the technology used by *MMWR* to distribute the publication by e-mail had become antiquated. In February 2009, *MMWR* switched to a new Web-based system that made subscribing to *MMWR* easier. This change, combined with a huge public interest in 2009 pandemic (H1N1), vaulted *MMWR*'s electronic circulation from approximately 50,000 in 2007 to 100,000 in 2010. By August 2010, with the remaining print subscription base of about 13,000, *MMWR*'s total circulation had reached almost 115,000, near the level at which it stood before the budget cuts of 1982. Together with articles reprinted to *JAMA's* subscribers, approximately 1 million monthly visits to the *MMWR* website, podcast downloads of 50,000 per week, and *MMWR* followers on Facebook and Twitter, by its 50th anniversary at CDC in 2011, *MMWR* was seen by a bigger and broader audience than ever before.

The Future

When the Internet began to emerge into common use in the early 1990s, no one could have imagined the revolutionary effects it would have on medical and public health communications. One effect on *MMWR* has been to create competitors for *MMWR*'s traditional mission of bridging the gap between immediate news media reports of public health events and later scientific publication (*5*). Today, medical journals are able to publish scientific articles more quickly than before through electronic means. During the recent outbreak of pandemic (H1N1) influenza, *The New England Journal of Medicine* electronically published information about the epidemiology of the disease within just a few days of data collection (*33*).

In 1961, and for decades afterwards, *MMWR* was the only way for CDC to mass-disseminate scientific information rapidly about public health events. Today, several other electronic channels exist at CDC for rapid communications about public health events: Epi-X (an electronic communication system for public health officials), the Health Alert Network (HAN), the Clinician Outreach and Communication Activity (COCA), satellite or Internet-based conferencing, mass e-mails, and informal posting on the Web. During the recent influenza pandemic, CDC relied on all these channels to communicate epidemiologic data and recommendations to state and local health departments and the medical community and relied especially heavily on informal postings on the Web. Ten years from now, a historian who wishes to trace CDC's work on the pandemic will consult *MMWR's* archives, but also will be obliged to consult electronic materials on the Web and other channels, if they are still accessible.

Despite these pressures, *MMWR's* traditional role continues. Informal Web postings, attractive as they might be, do not receive the rigorous review and editing that *MMWR* content does, nor are they indexed in MEDLINE, something that authors still believe is important. Rapid public releases to the news media or to health-care providers generally do not contain the kind of detailed scientific information sought by public

** Shaw served as Acting *MMWR* Editor in the summer of 2006 and became Editor in January of 2007. He was succeeded by Ronald L. Moolenaar in 2010. *MMWR*'s first deputy editor is Christine G. Casey. Another deputy editor, John S. Moran, was added in 2010.

health and medical audiences. Medical journals, although much more nimble than ever before, cannot publish state or federal public health investigations within hours, nor replace *MMWR*'s central role as the official voice of CDC, nor publish lengthy official CDC recommendations or surveillance statistics. These functions will remain unique to *MMWR* into the future. As the future unfolds, new roles for *MMWR* will continue to appear as they have over the past 50 years, and *MMWR* will evolve to meet the needs of public health.

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The Cornerstone of Public Health Practice: Public Health Surveillance, 1961–2011

Lisa M. Lee, PhD
Stephen B. Thacker, MD
Office of Surveillance, Epidemiology and Laboratory Services, CDC

Corresponding author: Lisa M. Lee, PhD, Office of Surveillance, Epidemiology, and Laboratory Services, 1600 Clifton Road, N.E., MS E-94, Atlanta, GA 30333; Telephone: 404-498-6010; Fax: 404-498-6365; E-mail: LMLee@cdc.gov.

Introduction

The roots of modern public health surveillance took hold in 17th century Europe (*1*), but the seed for CDC's role as America's national agency for collecting, analyzing, interpreting, and using data to protect the public's health was firmly planted only in 1961, when the *Morbidity and Mortality Weekly Report* (*MMWR*) was transferred to what was then the Communicable Disease Center (CDC; now the Centers for Disease Control and Prevention) (*2*). The advent of *MMWR* at CDC marked the beginning of CDC's responsibility for aggregating and publishing data weekly on nationally notifiable diseases and publishing the data annually in *MMWR's Summary of Notifiable Diseases, United States*.

The Beginnings of Modern Public Health Surveillance in the United States

In its earliest incarnation in the United States, surveillance took the form of morbidity reporting. By 1925, the year all states began reporting regularly, the expectations were limited to collecting, compiling, and publishing statistics in weekly reports. By the 1950s, however, simply compiling and reporting statistics clearly was insufficient to alleviate disease threats, and the National Surveillance Program was started. That program and the Malaria Surveillance Program, which had started 2 years earlier, were based on the notion that effective disease control cannot occur without implementing new ideas and expanding use of data collected (*3*).

Nowhere was the idea of connecting public health surveillance data directly to public health action more successful than during the 13-year global effort to eradicate smallpox. During 1966–1978, the initial tools for eradication were public education and mass vaccination. When the disease returned in some areas thought to have reached elimination, timely, complete surveillance and ring vaccination (i.e., administering vaccine to persons in close contact with an infected patient) enabled the program to turn the corner on eradication (*4*).

Effective national disease surveillance was an idea that captured the imagination of Alexander D. Langmuir, CDC's chief epidemiologist for 23 years. In 1963, in his sentinel paper published in the *New England Journal of Medicine* (*5*), Langmuir separated the discipline of surveillance from the other activities of public health and emphasized the importance of systematic collection of pertinent data, consolidation and analysis of these data into useful information, and dissemination of results to persons who need to know and can take action. These concepts were argued convincingly to the World Health Assembly as the approach for monitoring communicable and noncommunicable health events; subsequently, surveillance systems were developed, and findings from these systems were highlighted in a special issue (volume 5, number 1) of the *International Journal of Epidemiology* in 1976.

During the 50 years since Langmuir published his concept of public health surveillance, developments in four areas have changed the field: 1) national coordination, 2) technology and informatics, 3) expansion beyond communicable diseases, and 4) methodologic development. Through these, however, the core definition and integrity of surveillance practice have remained unchanged.

National Coordination of Public Health Surveillance

The United States Constitution leaves responsibility for public health practice primarily to the states as part of their police powers (*6*). The federal government, however, retains important roles. A major role in public health surveillance for CDC is to provide the national epidemiologic profile, through aggregation of surveillance data provided by the states, for the most important diseases and conditions. Having accurate and useful data requires that surveillance methods be coordinated across the 50 states and other independent jurisdictions that conduct data collection. Coordination includes establishment of consistent case definitions, collection methods, and population coverage; it requires that the data be deduplicated to avoid

inaccurate counting and that additional case information be matched accurately to avoid data errors.

Recognition of the federal role in surveillance led to considerable work during the 1970s and 1980s, when national coordination became a major emphasis for public health surveillance. CDC and the Council of State and Territorial Epidemiologists (CSTE), initially convened by CDC as the Conference of State and Territorial Epidemiologists in 1952 to bring states together to address shared concerns regarding public health, annually spent hours in consultations and symposia working on ways to coordinate public health surveillance. A report released in 1977 (J.L. Gale, Surveillance data: quality, use and effect on public health divisions in local and state health departments, unpublished report, 1977) called for national surveillance activity coordination at CDC. A year later, in 1978, the Consolidated Surveillance and Communications Activity was established to respond to the recommendations of Gale's report. These activities fostered a new emphasis on the scientific bases of surveillance, including the introduction of new statistical methods (e.g., time-series analysis), formation of the Surveillance Coordination Group that included the major CDC programs and CSTE, and introduction of changes to the *MMWR* weekly and *Annual Summary of Notifiable Diseases*. These activities also led to the first comprehensive CDC plan for public health surveillance, which was created in conjunction with state partners and CSTE and appeared in 1985 (*3*). The plan was designed to be flexible, with quick and easy updating, done simply by the click of a three-ring binder and removal and reinsertion of paper copies of critical sections. This document started with a surveillance definition that expanded the one formulated by Langmuir and was agreed on by leaders of all programs at CDC, both infectious and noninfectious diseases, and by CSTE. The plan emphasized the importance of consistency in the seven steps that are now recognized as part of any surveillance system: 1) system design, 2) data collection, 3) collation, 4) analysis, 5) interpretation, 6) dissemination/communication, and 7) application to program.

National coordination of these steps was implemented in the mid-1980s, when the most complex and well-funded national surveillance system ever created in the United States began to track cases of a new devastating immune-compromising disease, acquired immunodeficiency syndrome (AIDS). What eventually became the National HIV/AIDS Surveillance System (*7*) began with great forethought and consideration of the utility and applicability of the data collected at the national and state levels. From the start, all cases reported to the system were subject to the same case definition (*8*), and changes to the case definition (*9*) went into effect uniformly on the same date in every state. The same data elements were collected on the same case report form in all states and reported by using the same software. A system of deduplication activities to ensure accurate case counting was implemented early and included two key tools. The first tool emanated from a CSTE resolution (*10*) and permitted cross-state communication of case information among the 50 states allowing public health surveillance personnel to establish whether similar-looking cases were the same individual reported more than once to the system. The second tool was special statistical programming conducted on the national database to search for possible duplicates (*11*). This coordination continues today in the National HIV/AIDS Surveillance System. Similar coordinated case reporting exists for other nationally notifiable diseases (e.g., tuberculosis).

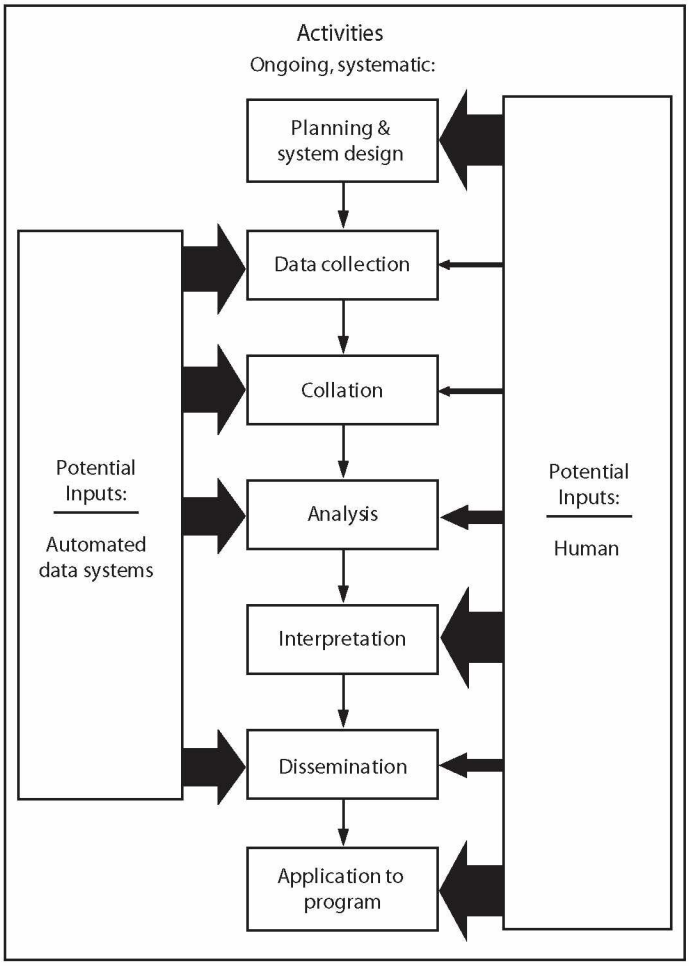
Today, public health surveillance remains an activity of the states, but CDC continues to carry out its national role by coordinating national public health surveillance activities with the states, CSTE, and other partners, including the Association of State and Territorial Health Officers, the National Association of City and County Health Officers, the Association of Public Health Laboratories, the National Association for Public Health Statistics and Information Systems, and the World Health Organization (WHO). In 2009, these partners came together with CDC to discuss challenges and a new vision for the future of public health surveillance in the 21st century.

Technology, Informatics, and Public Health Surveillance

Technologic advances began to improve the timeliness and accuracy of public health surveillance in 1961 when CDC implemented weekly telegraphic reporting by states for cases of notifiable diseases. This technology remained state of the art until 1975, when telephone reporting of nationally notifiable diseases began. In 1981, in addition to routine postcard reporting, telephone reporting began including interactive data transfer to a computer of the aggregate numbers for publication in *MMWR*. In 1984, CDC and six states piloted the Epidemiologic Surveillance Project (ESP), which experimented with electronic transfer of individual, de-identified case record data to CDC. By 1989, all 50 states and selected territories were participating in the National Electronic Telecommunications System for Surveillance (NETSS), which still exists for data transfer of the majority of nationally notifiable diseases. This leap forward allowed unprecedented reductions in counting and transcription errors and began the ability to remove human error in several of the ongoing, systematic steps in a surveillance system (Figure).

Today, the role of public health informatics and information technology in public health surveillance is twofold: 1) to improve timeliness and completeness of data collection and

FIGURE. Optimal balance of human and automated inputs into ongoing, systematic public health surveillance system activities*



* The size of the arrow indicates the relative human and automated inputs into each activity

analysis and 2) to free human resources to focus on the areas that require the most creative thought and to do the work that technology cannot. The idealized mix of technologic and human inputs into a public health surveillance system are illustrated in this report (Figure). With effective informatics tools, automated data systems can reach into electronic health records and extract data for public health surveillance, relieving the time-consuming and expensive "shoe-leather" data collection of chart reviews, paper forms, and morbidity cards that have characterized traditional reporting. Health information exchanges, which mobilize health information electronically across organizations within a jurisdiction, will provide a timely, efficient, and accurate means of data exchange and are an example of an informatics tool that holds considerable promise for public health.

During spring 1995, the CDC/ATSDR Steering Committee on Public Health Information and Surveillance System Development promulgated a blueprint for the agency's highest priority objective: the creation of integrated public health information and surveillance systems (*12*). The Steering Committee, comprising representatives from all centers, the institute, and offices at CDC, anticipated the impact of health reform and accompanying data collection and storage reforms and responded with sweeping recommendations for an integrated information and surveillance system. The blueprint envisioned coordinating the disparate and fragmented existing CDC surveillance systems to enhance functionality and efficiency. The purpose was to minimize the need for separate systems while maximizing the analytic value of the data for public health action. However, attaining a meaningful integrated information and surveillance system has proven more challenging than anticipated. Efforts continue to realize a fully functional integrated electronic health information system that begins at the clinical encounter and seamlessly connects through the ongoing activities of public health surveillance, with federal investments in electronic health records (*13*). Ensuring, through "meaningful use" requirements (*14*), that public health is at the collective table in formulating the requirements for software development is critical for the future of public health surveillance.

Electronic algorithms that collate data from disparate sources are critical to improving accuracy and timeliness as person-based surveillance records are connected across time. This is especially important in registry-based surveillance systems (e.g., HIV [*7*] and cancer [*15*]) where connecting subsequent events to the correct case is essential for accurate analyses. Using consistent statistical programs across jurisdictions and across time allows for timely and comparable analyses, which increasingly are important as the demands on public health surveillance data increase (e.g., distribution of resources according to disease burden, or support of public health program spending based on evidence of outcomes). In addition, new computer programs and applications can help public health programs better disseminate and communicate surveillance results. For example, they can help create understandable and interactive graphical representations of surveillance data that can tell stories to different audiences, including those untrained in health or public health (e.g., policymakers and the general public). Reaching such audiences is a critical step for using surveillance information for action, the last defining step of a public health surveillance system.

Technology assists public health practitioners by spreading information for action quickly and broadly, reaching program partners and others responsible for action. An example occurred at the start of the severe acute respiratory syndrome (SARS) epidemic in 2003, when the need for a practical, consistent case-finding tool quickly became evident. The Milwaukee

Health Department was able to adapt an innovative informatics tool called the Regional Emergency Medical Internet (REMI) to help find and triage SARS cases. The tool was implemented rapidly and inexpensively in 27 hospital emergency departments (EDs) within 3 days after pilot-testing in a single Milwaukee hospital (*16*). REMI had been designed originally to assist EDs communicate when they must divert ambulances and had been adapted by the health department into a multi-ED surveillance system to tackle different syndromic illnesses, from heat-related syndromes to potential biologic terrorism occurrences during international sporting events (*17*). Another example of rapid, innovative adaptation of surveillance technology occurred during the 2010 Deepwater Horizon oil spill. CDC's BioSense syndromic surveillance system was used to help the five affected Gulf states monitor the health (including mental health) of affected populations after the spill. With a daily report from 86 coastal health-care facilities, BioSense assisted with ongoing, up-to-the-day evaluation of possible health concerns (*18*).

Continued use of public health informatics promises more efficiencies in public health surveillance. As time and mental energy are freed for the surveillance scientist to focus on developing and improving systems and applying evidence to program implementation, usefulness of public health surveillance will continue to increase.

Expansion of Public Health Surveillance beyond Communicable Diseases

Until 1970, the "CDC" acronym stood for the Communicable Disease Center, indicating the strict focus of CDC on prevention and control of communicable diseases. In 1970, the agency's name was changed to the Center for Disease Control; then in 1980, to the Centers for Disease Control; and finally, in 1992, to the Centers for Disease Control and Prevention. The name change in 1970 signaled an expansion of CDC's mission to include prevention of unnecessary illness and premature death from all causes, infectious and noninfectious. The focus of CDC's activities broadened to include prevention of the major chronic conditions, including heart disease, cancer, stroke, and unintentional injury, and their associated risk behaviors (e.g., smoking, sedentary lifestyle, inadequate nutrition, and use of passenger restraints). In 1984, a total of 15 states and CDC began collecting information monthly about risk behaviors related to the leading causes of death through the Behavioral Risk Factor Surveillance System (*19*). In addition, CDC and its surveillance partners began communicating findings for action, including descriptions of the new surveillance systems for injury (*20*), chronic diseases (*21*), and environmental health tracking (*22*). *MMWR*, seeking a way to standardize reporting of data from the increasing number and types of surveillance systems and condition-specific surveillance reports, began publishing a new series called *CDC Surveillance Summaries* in 1983, which continues today. The first issue of *CDC Surveillance Summaries* contained reports on multiple topics, including summer mortality from selected cities and counties as reported by medical examiners, temporal trends in malformation incidence reported to the birth defects monitoring program, and psittacosis cases in the United States in 1979 (*23*).

After the events surrounding September 11, 2001, interest increased in using surveillance methods to detect unusual health events that might indicate public health emergencies: naturally occurring or human-made. Three outgrowths of public health surveillance came from this. The first, syndromic surveillance, is defined as the ongoing, systematic collection, analysis, interpretation, and application of real-time (or near–real-time) indicators for diseases and outbreaks that allow for their detection before public health authorities otherwise note them (*24*). Syndromic surveillance has been enhanced by new technology and statistical methods that can help identify disease patterns that would not be noted otherwise. The second outgrowth, biosurveillance, stemmed from a 2007 U.S. homeland security presidential directive that addressed activities beyond the scope of public health surveillance to include data collection for event detection, enhanced collection and analysis for event characterization, further data collection for situation awareness, and additional data collection for investigation and recovery activities (*25*). The third outgrowth was the recognition that, with modern transportation, most of the world's populations live just one incubation period away from other persons on the planet, and the health of one population is related to the health of others. These developments have kept CDC closely involved in international health (see global health article in this issue), including international public health surveillance. In 1992, CDC and WHO sponsored a 3-day international symposium on public health surveillance. Held at the Carter Center in Atlanta, the symposium had three goals: 1) foster an understanding of the role of public health surveillance in reducing morbidity and mortality, 2) identify topics for further development at future meetings, and 3) bring experts together to describe a new global agenda for public health surveillance (*26*).

A decade later, on the heels of the SARS epidemic (*27*) and in the midst of threats of influenza pandemics, revision of the International Health Regulations in 2005 (IHR 2005) and their implementation in 2007 were crucial events for international public health surveillance and served as a tool

for countries to communicate about possible international epidemics. IHR 2005 replaced the three notifiable diseases or pathogens listed in the original IHR, written in 1969, with a specifically defined "public health emergency of international concern" (*28*). IHR 2005 requires all member states to report a public health emergency of international concern within 24 hours. It also requires WHO to provide guidance and technical assistance to member states to develop and strengthen public health surveillance and response capacity. CDC participates in similar technical assistance activities, with 35 self-sustaining programs in 20 countries in which field epidemiology and laboratory training programs help educate local public health staff in surveillance methods as part of broader curricula since 1980 (*29*).

Advancement of Surveillance Methods

Throughout the past 50 years of surveillance activities, public health surveillance scientists have been developing methods to advance the field by coordinating methods among systems, applying advanced technology, and expanding systems to meet the surveillance mission. Methods advancement has occurred across the spectrum of the seven ongoing, systematic activities of a surveillance system (Figure).

In 1986, CDC developed a comprehensive plan for what was then called *epidemiologic surveillance*. This plan (*30*), developed by CDC's Surveillance Coordination Group, defined surveillance as follows:

> The ongoing, systematic collection, analysis, and interpretation of health data is essential to the planning, implementation, and evaluation of public health practice, closely integrated with the timely dissemination of these data to those who need to know. The final link in the surveillance chain is the application of these data to prevention and control. A surveillance system includes a functional capacity for data collection, analysis, and dissemination linked to public health programs.

The 1986 plan included the first proposed method for evaluating a surveillance system (*31*), which was the precursor to the more formal *Guidelines for Evaluating Surveillance Systems* published in *MMWR* in 1988 (*32*) and its updated version, *Updated Guidelines for Evaluating Public Health Surveillance Systems* published in *MMWR* in 2001 (*33*).

The definition of public health surveillance has remained stable across time, even as public health experts have debated the purpose and meaning of surveillance. During the 1970s, Langmuir argued that the boundaries of surveillance stopped at "epidemiologic intelligence" and that it did not encompass all of epidemiology (e.g., investigations and research) (*34*). In 1988, Thacker and Berkelman suggested a new name, *public health surveillance* (*35*), to indicate its scope and context. In 2009, approximately 20 years after the last time the definition had been reconsidered, CDC gathered 100 surveillance scientists to discuss special topics in public health surveillance in the 21st century, including its definition. After careful consideration addressing the drivers of health information in the coming century, the group recommended maintaining the existing definition of *public health surveillance* because it remains applicable and flexible to accommodate public health needs across the spectrum of topic areas. However, the group recommended incorporating explicitly two key principles: 1) the purpose of the activity must be to address a defined public health problem or question and 2) the public health question(s) must exist *a priori*, that is there must be a planned public health purpose to the collection, storage, and use of the data.

A tenet of modern surveillance is that the utility of surveillance is determined largely by proper analysis of the data. Herman Biggs, the 19th century physician who pioneered public health surveillance in New York City, was known for insisting that collected data be used to improve health, not merely to keep "adding machines" busy (*36*). To be useful, surveillance data must be converted into information for public health action. Fortunately, the tools used for analysis have improved substantially since 1961. For example, the ability to differentiate "noise" from true aberrations in the data has been a problem keeping surveillance scientists occupied for years (*37*). This problem plays out in surveillance for influenza, a public health priority since 1918 when a system was established by the U.S. Public Health Service in 50 cities based on death certificates (and is still maintained today by CDC in 122 cities and published weekly in *MMWR*). Influenza surveillance was a priority for Langmuir, who worked with colleagues Serfling and Sherman to develop a seasonal regression model that could help analyze influenza mortality data more precisely than previous methods based on the moving average (*38*). In 1979, pneumonia and influenza data were modeled by using time-series analyses to identify aberrations in incidence (*39,40*); today, other systems (e.g., anthrax [*41*] and syndromic surveillance [*42*]) routinely use these methods to model surveillance data. Application of epidemiologic study designs to examine efficacy of different types of surveillance methods and approaches has also been accomplished. In the early 1980s, two innovative randomized clinical trials evaluated active surveillance strategies compared with passive reporting. Both studies, one in Vermont (*43*) and one in Monroe County, New York (*44*), demonstrated substantial improvements in completeness using active surveillance strategies for communicable diseases. Differences

in improvement were observed by disease and report source, leading to the conclusion that in the analysis of surveillance data, knowing and attending to the local context is desirable. This conclusion remains critically important today.

By the early 1990s, many schools of public health in the United States had begun to focus on the science of public health surveillance, and the lack of a textbook was obvious. Until *Public Health Surveillance* was published in 1992 (*45*) and the first edition of *Principles and Practice of Public Health Surveillance* was published in 1994 (*46*), surveillance practitioners were able to rely only on journal articles, consultations convened by CDC, and professional exchanges to share methodologic advances and preferred practices. Now the *Principles* text is in its third edition (*47*), and additional texts have been published, including one devoted to statistical principles and methods of public health surveillance (*48*) and another to infectious disease surveillance (*49*). As the science of public health surveillance continues to evolve and the tools of public health informatics become integral to the work of surveillance practitioners, methods will continue to develop that enable the public health epidemiologist to put data to use in the most effective way.

The Future of Public Health Surveillance

Evidence-based decision making in public health begins with surveillance—and the demands on health data continue to increase. The ways of knowing about the health of a community also continue to evolve as information technology eases the effort to collect, collate, store, analyze, and disseminate data. The integrity of the discipline of public health surveillance has held fast for the past 50 years and most likely will continue for the next 50 and beyond. The tools available to public health surveillance practitioners and scientists will change as technology improves efficiency and frees practitioners to attend to creative problem solving in such critical areas as program planning and applying data to action. CDC will continue to evaluate its efforts and move the field forward, welcoming the opportunities that lie ahead.

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Evolution of Epidemic Investigations and Field Epidemiology during the *MMWR* Era at CDC — 1961–2011

Philip S. Brachman, MD[1]
Stephen B. Thacker, MD[2]
[1]*Rollins School of Public Health, Emory University, Atlanta, Georgia*
[2]*Office of Surveillance, Epidemiology and Laboratory Services, CDC, Atlanta, Georgia*

Corresponding author: Philip S. Brachman, MD, Rollins School of Public Health, Emory University, 1518 Clifton Road, Atlanta, GA 30322. Telephone: 404-727-0199; Fax: 404-272-4590; E-mail: pbrachm@sph.emory.edu.

Introduction

Since 1946, CDC has provided rapid assistance to states, federal agencies, international organizations, and ministries of health, often through formal requests for epidemic-assistance investigations (Epi-Aids) (*1*). The Epi-Aid mechanism provides CDC with the agility to respond rapidly to serious and urgent public health crises. Epi-Aids operationalize the tenets of field epidemiology and are used to provide information, as quickly as possible, on which the processes of selecting and implementing interventions can be based to lessen or prevent illness, injury, or death (*2,3*).

A total of 4,997 Epi-Aids have been conducted, of which 4,673 (94%) have occurred since 1960. Of the 556 international investigations, 551 (99%) have occurred since *MMWR* was transferred to CDC in 1960. Approximately 90% of these investigations have involved the approximately 3,000 Epidemic Intelligence Service officers (EISOs) who have trained at CDC since the program was initiated in 1951; however, only 218 EISOs came to CDC before *MMWR* arrived. EISOs assigned to state and local health departments conduct additional investigations within the states to which they are assigned. During the past 50 years, EISOs collectively have conducted approximately 5,000 state-based investigations without using the formal Epi-Aid request mechanism.

The goal of Epi-Aids is to control an epidemic and to prevent future epidemics attributable to the same or related causes. The specific objectives of an investigation are to define the parameters of the epidemic (i.e., time of illness onset and conclusion of the epidemic, number of cases, and morbidity and mortality), to identify control or prevention measures, and possibly to identify new data relative to the epidemiology of the health problem. Epi-Aids always are performed collaboratively with partners domestically or internationally.

Justification for investigating epidemics include

- increased disease or injury severity (e.g., its morbidity or mortality or other determinants of severity);
- occurrence of a rare or unknown disease or a change in the pattern of the disease's occurrence;
- opportunity to identify new information (e.g., risk factors previously unassociated with that disease or a change in transmission method);
- occurrence among a particular population (e.g., children or older persons);
- public or political concern;
- opportunity to conduct research on a specific disease; and
- opportunity to train personnel (e.g., EISOs or state and local field investigators) in the methodology of field investigations.

The 13 steps in an epidemic field investigation (Box) are adaptable to the circumstances of the problem, resources available, or cause or suspected cause of the disease. Altering the order of the steps might be necessary (e.g., possibly instituting control measures before completing data analyses), but all of the steps should be completed. These steps are as valid today as they were during the first field investigations over a half century ago, but the methodology of field investigations has evolved, as has the complexity of epidemics.

Four evolutionary changes throughout the past 50 years have resulted in more comprehensive investigations, as observed through *MMWR*. They include

- improved tools in science, technology, and communication;
- broader scope both in terms of geography and the nature of the public health problems under investigation;
- a better trained and equipped workforce that includes not only epidemiologists, public health advisors, microbiologists, and statisticians, but also behavioral and social scientists, economists, informaticians, toxicologists, and chemists; and
- new or changed roles for CDC's public health partners (e.g., U.S. Environmental Protection Agency, Department of Justice, Department of Housing and Urban Development, Department of Homeland Security, and Federal Bureau of Investigation and local law enforcement) and enhanced collaborations with the Indian Health Service; the U.S. Department of Agriculture; the Food and Drug Administration; the National Institutes of Health; the World Health Organization; and the private

BOX. The 14 steps of an epidemic investigation

1. Confirm the existence of an epidemic.
2. Verify the diagnosis.
3. Develop a case definition.
4. Develop a case report form.
5. Count the cases (i.e., an approximate analysis).
6. Orient the data (i.e., time, place, and person).
7. Analyze the data (e.g., agent, transmission, and host).
8. Develop a hypothesis.
9. Test the hypothesis.
10. Plan and implement control and prevention measures.
11. Evaluate the implemented measures.
12. Establish or improve the public health surveillance.
13. Write a report.
14. Plan and conduct additional studies.

sector, including the business community, academia, community-based organizations, health plans, professional societies, volunteer agencies, and international organizations.

Before *MMWR* was transferred to CDC in 1960, most Epi-Aids were conducted in response to infectious agents, although environmental problems, including disasters, also were addressed. Subsequent years continued to include investigations of infectious disease epidemics but increasingly included environmental exposures, birth defects, genetic diseases, reproductive health, tobacco, cancer, unintentional injury, violence, legal debate, and terrorism. These Epi-Aids heralded expansion of CDC's mission and included new methods in statistics and applied epidemiology. Recommendations from these investigations have led to implementation, evaluation, or modification of public health policies. For example, during the 1970s, salmonellosis among children throughout the country was investigated, and the risk factor was contact with baby semi-aquatic turtles sold in pet stores. Subsequently, sale of these turtles was banned (*4*). During the 1990s, an epidemic of *Escherichia coli* O157:H7 diarrhea was investigated, and the risk factor was identified as eating undercooked hamburgers served at multiple fast-food outlets of one chain (*5*). A new policy of serving only well-cooked hamburgers was implemented.

The tools available to epidemiologists have evolved since 1961 and have been adapted to address whatever emergent health problems arise. Evolution of statistical methods in the acute setting of the Epi-Aid reflects a similar pattern in other public health disciplines (*6*). Especially notable are 1) the increased use of multivariate modeling beginning in the late 1970s, paralleling advances in computer hardware, especially the laptop, and 2) advances in computer software, most notably the CDC-sponsored Epi Info, an open-source software package developed in the 1980s for practicing epidemiologists and now translated into 14 languages (*7*).

Similarly, advances in laboratory practice have kept pace with the complexities of the investigations (*8*). For example, in 1961, the distance between the food source and the dinner table was considerably shorter than today, when a substantial amount of food is transported across the United States or imported from abroad. A public health official 50 years ago usually could not detect an outbreak until a substantial number of cases emerged in a single area or from a single event (e.g., a picnic or party). Today, in contrast, use of pulsed-field gel electrophoresis to create a DNA fingerprint enables associating a limited number of cases of a disease throughout a wide geographic area with a single common source. PulseNet, the laboratory-based foodborne diseases surveillance system, benefits not only from enhanced information science but also from increased diagnostic specificity (*9*). An example of the importance of this new technology was the epidemic of *Salmonella enterica* serotype Tennessee caused by contaminated peanut butter products in 2006–2007, with cases occurring in 47 states (*9,10*). DNA identification demonstrated that the cause of the epidemic was peanut butter from one factory, which when investigated, revealed multiple problems in its production process. Because the epidemiologic capacity of state and local health departments is higher now than in former years, for large outbreaks, CDC's role today often has become one of national coordination of multiple state-based investigations. EISOs in the field join with state and local colleagues to conduct parts of a larger nationwide investigation.

These advances, as well as others (e.g., geographic information systems), have enabled extraction of more data from field investigations and have increased the ability to determine the cause of an adverse health outcome. Descriptive epidemiology alone can help determine causation, but increasing knowledge of the multifactorial causes of disease has made involvement of the laboratorian and statistical analyses of the data of prime importance in deriving valid conclusions regarding cause and effect.

Steps in an Investigation

Despite the availability of new technology, what has not changed is the need for careful and thorough data collection and rigorous analysis of those data, thoughtful interpretation of the findings, and the willingness to continue to question the findings while confronted with the primary objective — to control a problem quickly and effectively. The essential steps remain the same as in 1960.

When epidemiologists receive information about a possible epidemic, they should confirm its existence by comparing reported data with public health surveillance data collected during previous years (Box). If surveillance data for a particular disease or syndrome are unavailable, local health officials might be able to provide an informal assessment of past occurrence of the condition within their community. For many outbreaks, investigators can help confirm the diagnosis by submitting specimens for examination to a state or local laboratory, or sometimes to CDC. However, for some outbreaks, methods of confirmation are unavailable, and the investigation has to be initiated without confirmation of the diagnosis.

In planning participation in an investigation, the investigator must consider what materials should be taken into the field that will be unavailable locally. This might include specimen collection equipment; laboratory equipment; a calculator; a laptop computer; a generic or standardized questionnaire; reference material about the disease; and possibly, personal protective equipment. In 1961, neither the calculator nor the laptop was available. Specimen collection and laboratory equipment, as well as personal protective equipment, have changed dramatically, and today these tools often are available locally. Today, many investigations that would have resulted in an Epi-Aid request to CDC are handled locally, although still often reported in *MMWR* (*11*).

For Epi-Aids involving invited CDC staff, upon arriving at the scene of the epidemic, investigators meet with the local health authorities who requested assistance to discuss the information that has been developed locally. An immediate decision should be made regarding who will be in charge of the investigation and who will provide media reports. The investigators should, with appropriate permissions, examine selected patients to verify the diagnosis and develop a differential diagnosis of the cause of the outbreak. From the initial assessment of the clinical and epidemiologic information, a case definition should be established. Depending on the nature of the disease and the objectives of the investigation, the case definition should be either broad or narrow, which influences its sensitivity and specificity.

Data collected every day should be analyzed at the end of that day because identifying a control measure or measures before all cases have been recognized might be possible. Clearly this depends on the epidemic but is an important consideration in all investigations. For example, an epidemic of hepatitis A in Pascagoula, Mississippi, in 1961, might have disrupted production by a local company of atomic submarines for the U.S. Navy had it continued (*12*). Upon arrival in Pascagoula, by using a local directory, the investigating epidemiologist contacted patients by telephone. After completing interviews with selected patients, the epidemiologist contacted an equal number of controls. An analysis of these data at the end of the first day of the investigation strongly indicated that ingestion of raw shellfish was the risk factor involved. The epidemiologist was able to come to this conclusion before interviewing all of the patients. On the basis of these early findings, a decision was made to publicize the problem and to recommend that raw shellfish no longer be eaten. This action terminated the occurrence of new exposures; after completing interviews with all patients, the initial preliminary conclusion was confirmed.

Early in an investigation, categorizing cases as possible, probable, or confirmed on the basis of available data and knowledge is often necessary. An example of the importance of categorization occurred during the investigation of Legionnaires disease in Pennsylvania in 1976. The initial case definition required that patients had been in the main conference hotel. Illnesses of certain other patients met the clinical case definition except that they had not been in the hotel; thus their illnesses were put in a separate category called "Broad Street pneumonia." Later, after the etiologic agent was identified and a serologic test developed, the Broad Street pneumonia cases were recognized as cases of Legionnaires disease, just as the cases in the hotel. The Board Street pneumonia cases were included in the final tabulation for the outbreak.

The 1976 Legionnaires disease investigation also illustrates the key role of *MMWR* in keeping the medical and public health communities informed through updates in the weekly report. The first report was published less than a week after CDC was notified of the epidemic (*13*). Four more updates followed, with the last reporting identification of the bacterium that caused the disease (*14*) 11 months before publication in a peer-reviewed journal (*15*). This last report was also the first *MMWR* article published on a day other than Friday, highlighting the urgency in reporting the findings.

After all the patients have been interviewed during an investigation, the data should be oriented by time, place, and person. Then a hypothesis should be developed on the basis of the data that have been collected. It should be a unifying hypothesis (i.e., one risk factor related to the epidemic), recognizing that multiple risk factors might be involved. If uncertainty exists about the hypothesis, an analytic investigation (e.g., a case-control or cohort study) might be needed. After a hypothesis has been identified that fits the facts, corresponding control and prevention measures should be determined and implemented. Surveillance must be maintained to evaluate whether the hypothesis was correct and the control strategy is working. If the number of new cases decreases and the decrease is believed to result from the control measures, the investigation

can be completed by writing and disseminating the final report. However, if cases continue to occur, the investigation has to be continued and different hypotheses tested. This happened during an outbreak of S. enterica serotype Saintpaul in 2008 in which approximately 1,400 persons in 43 states, the District of Columbia, and Canada were infected (*16*). Preliminary evidence implicated tomatoes as the transmission vehicle, but further epidemiologic and microbiologic investigations identified jalapeno and serrano peppers as the primary vehicles.

Recently epidemiologists have used the Internet as a tool for data collection, although the validity of that use remains under scrutiny. As noted elsewhere in this supplement (*17*), *MMWR* can reach tens of thousands of public health professionals in a very short time. The fact that the weekly edition can, in fact, be published electronically at any time, day or night, can facilitate case ascertainment in an ongoing investigation. Along with the effective outreach of *Epi-X* (a CDC-managed secure communications network for public health professionals) to public health partners, regional, national, and international case ascertainment is expanded (*18*). Meanwhile, the World-Wide Web has opened channels of communication that are more timely and far reaching than could have been imagined in 1961. Well-crafted, timely, and accurate updates of an investigation help the medical and public health communities, as well as the public, stay abreast of ongoing investigations, and they assist in implementing timely interventions to protect the public.

For CDC epidemiologists investigating outbreaks in the field, just as in 1960, writing a report is critically important. The report provides local public health departments an explanation of the parameters and the epidemic's cause, which enables timely and effective public health action. A secondary benefit of a report is its value as a useful training document for current staff and incoming epidemiologists. The report should identify the risk factors that resulted in the epidemic, and the report should be disseminated to the population involved in the epidemic to educate the public about control and prevention measures. Also, the report can be distributed to other public health professionals to help prevent a future similar problem.

The results of an investigation often indicate the need for other studies related to the disease or injury. For example, investigation of epidemics of Ebola virus hemorrhagic fever identified control measures (e.g., preventing contact with bloody secretions from patients or contaminated needles and syringes). What remains unknown and continues to be investigated is the reservoir for Ebola virus, which might be another mammal (e.g., primates) (*19*).

Future of Epidemic Investigations

New science and technology will continue to improve the epidemiologist's approach to outbreak investigation. Rapid technology development in the laboratory has improved diagnostic precision and reduced the time necessary to make a diagnosis. These improvements should continue, for example, to identify pathogens in imported foods at the place of importation and among persons who now travel more extensively and more rapidly around the globe. Similarly, increased use of electronic health records will facilitate more timely and accurate data collection as well as real-time dissemination of recommended control measures to clinicians and health-care facilities. Statisticians continue to develop new statistical methods that will provide insights through refined data analysis. For example, mathematical modeling, especially in complex and time-consuming investigations (e.g., pandemic influenza) can enable application of control measures to reduce the number of cases that are epidemic related. Improved techniques for training also need to be developed so that the technology of epidemic investigations can be used effectively by public health personnel both in the United States and internationally.

Alexander D. Langmuir, the man who brought *MMWR* to CDC in 1960, would be pleased with its first 50 years at CDC. It still often publishes the first scientific report of an unfolding epidemic investigation, and the reports continue through the different stages of the outbreak or incident. For example, on April 21, 2009, *MMWR* published a rapid report of the first cases of 2009 pandemic influenza A (H1N1) (*20*), and then published 45 articles on the virus and the pandemic in the subsequent several months, many reporting on ongoing investigations and others providing recommendations based on the findings of those investigations. Just as Langmuir envisioned, *MMWR* remains an important mechanism for reporting epidemic investigations in a timely and credible way.

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Laboratory Contributions to Public Health

Walter R. Dowdle, PhD[1]
Leonard W. Mayer, PhD[2]
Karen K. Steinberg, PhD[3]
Neelam D. Ghiya, MPH[4]
Tanja Popovic, MD, PhD[4]

[1]*Global Polio Eradication, Task Force for Global Health, Decatur, Georgia*
[2]*Division of Bacterial Diseases, National Center for Immunization and Respiratory Diseases, CDC, Atlanta, Georgia*
[3]*Division of Laboratory Sciences, National Center for Environmental Health, CDC, Atlanta, Georgia*
[4]*Office of the Associate Director for Science, Office of the Director, CDC, Atlanta, Georgia*

Corresponding author: Walter R. Dowdle, PhD, Task Force for Global Health, 325 Swanton Way, Decatur, GA 30030; Telephone: 404-687-5608; Fax: 404-371-1087; E-mail: wdowdle@taskforce.org.

Introduction

Alexander Langmuir, founder of the CDC Epidemic Intelligence Service (EIS), was quoted in the early 1960s instructing incoming EIS officers that the only need for the laboratory in an outbreak investigation was to "prove their conclusions were right." Understandably, this was not well received by the CDC Laboratory Branch. However, Langmuir's point was not to denigrate the laboratory but to emphasize the power of an investigation based on a solid clinical case definition and established field epidemiologic principles. In truth, in 1960, when CDC assumed responsibility for publishing *MMWR*, the laboratory provided little added value in many investigations, except to confirm "what the etiologic agent wasn't." Existing diagnostic laboratory procedures for infectious and noninfectious diseases of public health importance were reasonably reliable but basic and laborious. For diagnosis of many diseases and conditions, no laboratory procedures existed. Since 1961, advances in molecular sciences, analytical chemistry, and technology have revolutionized the public health laboratory investigative capacity, capability, and specificity and have emphasized the importance of more independent laboratory research. The term "molecular epidemiology" is widely applied, and the number of diseases for which laboratory diagnoses are available today is substantially larger. This article describes the principles and practices of the state-of-the-art public health laboratory in 1961 and provides examples of scientific, technologic, and strategic advances since that time that characterize the still evolving public health laboratory of the 21st century.

Browsing through *MMWR*, volume 10, week 1, January 13, 1961, provides insight into the public health laboratory of 1961 and the topics of most interest and visibility at that time. Subsequently, progress and contributions made by the public health laboratories are provided in a more detailed account by using several illnesses and conditions of public health importance as examples. They span both infectious and noninfectious arenas. Some were listed in the first *MMWR* summary, but some were not under consideration in 1961 or were yet to be discovered.

The Public Health Laboratory of 1961

Poliomyelitis (3,190 cases in 1960) was the first disease discussed in the Summary section of the January 13, 1961, *MMWR* (*1*). The basic procedures for isolation and identification of polioviruses in cell cultures were slow but well developed, benefitting from 30 years of concentrated laboratory research to understand the disease and develop a vaccine. Week 33 published the Surgeon General's announcement that a license had been granted to Pfizer Inc. for the manufacture of the Sabin live oral polio vaccine (OPV) type 1. This attenuated strain was developed in the CDC laboratories in Montgomery, Alabama. Although a remarkable humanitarian achievement, the introduction of live vaccine into the environment and the clinical and epidemiologic need to differentiate vaccine strains from wild strains proved a major challenge to the laboratory.

Hepatitis was the second viral disease in the Summary section. The national hepatitis epidemic occurred in 1961. Shellfish were implicated for the first time. The laboratory was of little help because the etiologic agents were unknown. Outbreaks were differentiated into infectious or serum hepatitis on the basis of clinical and epidemiologic grounds, and the totals (72,651 cases in 1961) were combined.

Influenza A2 was the third disease noted in the Summary section. Because development of an influenza virus vaccine had been a high priority of the U.S. military during World War II to avert another 1918 disaster, basic procedures for virus isolation and serologic diagnoses were well established. Classification according to H (hemagglutinin) and N (neuraminidase) antigens was yet to come.

Rabies was a notifiable disease in humans and animals, with three and 3,599 cases reported, respectively, in 1961 (*2*). Diagnostic procedures were evolving from the traditional histologic staining for Negri bodies to specific fluorescent antibody staining, greatly increasing confidence in laboratory diagnosis.

Anthrax, commonly known as "wool-sorters disease," totaled 14 cases in 1961 (*2*). The laboratory diagnosis of *Bacillus anthracis* was based on traditional microbiologic methods,

some of which are still the cornerstone of laboratory diagnostics today: staining with the M'Fadyean polychrome methylene blue stain (developed in 1903) and susceptibility to lysis by the gamma phage (since 1951). Human vaccines for anthrax had already been developed in the United Kingdom and the United States. There were no prescribed special biosafety laboratory facilities.

Outbreaks of salmonellosis, shigellosis, staphylococcal food poisoning, pathogenic *Escherichia coli*, typhoid fever, and botulism were commonly reported in volume 10, week 1. Mingled among these reports were 25 apparent foodborne disease outbreaks of unknown etiology by mid-year. The need for discovery of new and more precise characterization of already recognized etiologic agents of diarrhea was evident.

Listed clinical conditions of unproven etiology included rubella, erythema infectiosum, and cat-scratch fever. Yet to come were rotavirus, *E. coli* O157, and HIV infections; Legionnaires disease; hemorrhagic fevers; and severe acute respiratory syndrome, to name a few. Roseola infantum, now known to be caused by one of eight human herpesviruses (type 6), exemplifies the progress made during the past 50 years. Only one (herpes simplex virus) was recognized in 1961.

Except for one naturally occurring nicotinic acid (niacin) toxin, *MMWR* contained no reports on noninfectious diseases. However, in 1961, CDC began a collaboration with the National Heart, Lung, and Blood Institute to expand the Cooperative Cholesterol Standardization Program with a goal of standardizing cholesterol measurements and, ultimately, decreasing deaths and disability from heart disease.

The following sections review these and other diseases and provide some insight into the scientific and technical advances that have revolutionized the public health laboratory capabilities during the past 50 years.

Poliomyelitis

The inability in 1961 to distinguish clearly between epidemic wild strains and attenuated OPV strains recovered from fecal samples led to numerous disagreements among advisory bodies on the etiology of potential cases of vaccine-associated poliomyelitis. The biology-based laboratory test then in use also figured prominently in the 1974 landmark legal ruling (*Reyes vs. Wyeth Laboratories*) on the liability of the manufacturer for failure to warn the public of OPV risks (*3*), despite the epidemiologic and biologic laboratory evidence that the causative virus was most likely wild. More reliable nonbiologic laboratory techniques were needed. By 1984, the laborious but definitive newly developed oligonucleotide fingerprinting technique confirmed the Reyes poliovirus isolate as wild (*4*).

The growing capabilities of the poliovirus laboratory coincided with the launch of the global polio eradication initiative in 1988. Continuously evolving molecular techniques and novel technologies eventually made possible the sequencing and comparing of poliovirus genomes in real time. Linking these advances to the newly established poliovirus evolutionary rate provided previously unimagined detailed information about individual poliovirus isolates. In 2000, genome sequencing identified the first outbreak of circulating vaccine-derived polioviruses, which continue to occur in areas with low rates of OPV coverage and document the urgent need to replace live with inactivated (killed) poliovirus vaccine (IPV) (*5*).

The 2010 *MMWR* report on polio eradication progress illustrates current laboratory capabilities (*6*). The Islamabad, Pakistan, polio laboratory, one of 147 laboratories in the polio network, processed >15,000 fecal and sewage samples and isolated 137 polioviruses in 2009. Genomic sequencing of these 137 isolates from Afghanistan and Pakistan provided data that identified virus origins, transmission zones of circulating wild viruses, and viruses that were not closely related. Information about virus origin and transmission inform the program of inadequately immunized populations. Distantly related viruses provide evidence of evolutionary gaps and inform the program of surveillance weaknesses that must be improved. Molecular epidemiology plays a key role in all aspects of the poliovirus eradication initiative.

Hepatitis

In 1961, a report of an outbreak of infectious hepatitis A among chimpanzee handlers (*7*) generated considerable interest, suggesting nonhuman primates might be possible models for human hepatitis. However, 18 years would pass before the virus would be propagated in cell culture, which would make laboratory diagnosis and a vaccine possible (*8*). In 1963, the serendipitous discovery of an antigen in human blood (*9*) led to the eventual association of this protein with serum hepatitis B and development of a highly effective vaccine in the early 1980s. The development of diagnostic tests for hepatitis A and B viruses led to recognition of three other etiologic agents (types C, D, and E). In few other infectious diseases has progress been as rapid and effects on disease reduction as dramatic.

Influenza

In 1961, lessons learned from the overwhelming laboratory workload during the A2 pandemic of 1957–58 were still being implemented. Expanded serologic diagnostic tests were being introduced for other newly recognized agents of acute

respiratory disease (parainfluenza, respiratory syncytial virus, and adenoviruses). The workhorse complement fixation (CF) serologic test deserves special mention to illustrate the labor-intense laboratory practices of the day. The test was performed over a 3-day period in a large room with two big tables specially designed for the purpose in the new (1960) virology laboratory building. The average run of paired serum samples from 50 patients used approximately 4,000 test tubes (all to be washed and reused), 60 wire test tube racks, and nearly 100 pipettes. On day 1, six antigens were prepared, test tubes marked, and serum sequentially diluted (by mouth pipette). On the morning of day 2, the four essential test reagents were prepared and standardized. In the afternoon, 8–10 laboratory personnel were rounded up; given instructions and pipettes; and marched around the table adding one ingredient in precise sequence. The racks were moved to a walk-in refrigerator. On the morning of day 3, the final indicator reagent was added and the results read, tube by tube, against the ceiling lights, trusting no one had added materials to the wrong test tubes or in the wrong sequence. Another 4 years would pass before that resource-intensive CF procedure would be aided by microtechniques and, later, by automatic pipetting machines (Figure 1).

Today, the CF test is rarely employed, but other serologic tests (neutralization and hemagglutination-inhibition), also used in 1961 to detect and quantify antibodies in patient's serum, remain in principle unchanged. The greatest advances in understanding the influenza virus closely parallel the phenomenal advances in molecular technology. Definitive characterization of influenza viruses, as in all other areas of virology, relies heavily on genome sequencing. The pandemic virus of 1918 was reconstructed by reverse genetics and genomic RNA recovered from archived formalin-fixed lung autopsy materials and from an influenza victim buried in the permafrost (*10*). The pandemic influenza A (H1N1) 2009 virus was demonstrated to be a triple genetic reassortant with an antigenic structure similar to those of the influenza viruses circulating early in the 20th century (*11*). Yet to benefit from these major breakthroughs in science is the killed influenza vaccine, which has seen only incremental improvements since 1961.

FIGURE 1. Laboratorians reading and checking serologic tests to determine presence of influenza A/NJ/8/76 (swine flu) and registering antibody rise to the swine influenza virus during vaccine testing trials. 1976

Photo: CDC

Anthrax

Major advances in the laboratory identification of *B. anthracis* were made during the 1980s by sequencing the structural genes located on one of the plasmids, pXO1, and encoding the three anthrax toxins (*12*). However, the real scientific renaissance of *B. anthracis* began in the mid-1990s as inhalation anthrax became the initial focus of the laboratory component of biothreat preparedness in the United States. Development of new diagnostic and molecular subtyping tools with emphasis on standardization and quality control led the path for establishing the Laboratory Response Network that was instrumental in analyzing approximately 200,000 environmental and clinical specimens during the 2001 anthrax attacks (*13*). Polymerase chain reaction (PCR) detecting three *B. anthracis*–specific loci allowed for rapid (a few hours) identification of this organism directly from clinical specimens. Multiple locus variable-number-of-tandem-repeat analysis (MLVA) made differentiating the *B. anthracis* strain and implicating the Ames strain in 2001 possible. Identification of an identical MLVA type in the clinical specimens of the patients and at their respective infection sources (e.g., offices, post offices) provided the laboratory confirmation that the events were intentional and not a result of natural exposure (*14*).

Laboratory research on *B. anthracis* continues post 2001. Although the first report of naturally occurring anthrax toxin genes in a species (*B. cereus*) other than *B. anthracis* adds complexity to the identification process, it also emphasizes the importance of vigilance and close collaboration between those treating the patients, the public health community, and the research community in ensuring that the true causative agents are identified rapidly and reliably (*15*).

Rapid detection in clinical specimens and molecular subtyping of biothreat agents, which were demonstrated to be of critical importance for public health response in 2001, are now the standard in approximately 150 Laboratory Response Network laboratories in the United States and worldwide.

This ancient disease is likely to continue to shape research and public health future issues.

Foodborne Diseases (PulseNet)

Methods for characterizing etiologic agents of diarrhea, such as multilocus enzyme electrophoresis and ribotyping, first became available and used during the 1980s. However, no method was broadly accepted and standardized for use on different organisms until after the *E. coli* experience of the early 1990s.

From November 1992 through February 1993, approximately 700 laboratory-confirmed infections with *E. coli* O157:H7 occurred in Washington, Idaho, California, and Nevada associated with ground beef. Distinct clinical presentation associated with this pathogen was first described in 1983 and subsequently recognized as an important cause of bloody diarrhea and the most common cause of renal failure in children (hemolytic uremic syndrome) (*16*). During the 1992–93 outbreak investigations, CDC used pulsed-field gel electrophoresis (PFGE) to characterize clinical and food isolates and distinguish outbreak-related and nonoutbreak strains (*17*). To satisfy the subsequent enormous nationwide demand for PFGE subtyping, standardized methodology was transferred to four state public health laboratories in 1995. This national molecular subtyping network for foodborne disease surveillance later became known as PulseNet (*18*) and was officially launched in 1998 by the White House.

PFGE continued to be an indispensable tool in a number of *E. coli* O157 outbreaks. Over time, the primary role of PFGE and PulseNet gradually shifted from a tool to investigate and compare outbreaks to a real-time surveillance, cluster-detection, and outbreak investigation system. One such PulseNet-detected outbreak in Colorado in 1997 resulted in the largest meat recall thus far (*19*). PulseNet quickly expanded to include other etiologic agents of foodborne diseases: *Salmonella* and *Shigella* spp, *Listeria monocytogenes*, *Campylobacter jejuni*, *Vibrio cholerae*, and *Yersinia pestis* (www.cdc.gov/pulsenet) and has gone on to receive awards as one of the most innovative government programs.

The impact of PulseNet on the nation's health has been enormous. PulseNet has been instrumental in improving foodborne disease surveillance and outbreak investigations, especially outbreaks in which the cause might be the same but affected persons are geographically far apart. Outbreaks and their causes now can be identified much faster. Critically important is the PulseNet approach to building public health infrastructure in state and local health departments with methods, equipment, and training that can be used broadly. Geographically localized outbreaks are no longer the norm. Foodborne illnesses do not respect borders. Food distribution, preparation, and consumption practices have changed worldwide during the past few decades so that food produced and prepared in one place can be sold and consumed worldwide. Consequently, PulseNet International, a network of national and regional laboratories, was created to track foodborne infections worldwide. Each laboratory uses standardized methods and shares the information within the network in real time. PulseNet is committed to introducing new and improved subtyping methods and strengthening collaboration with the food industry to prevent outbreaks.

At the time of the first *MMWR* publication at CDC in 1961, little was known about viral agents as causes of enteric diseases. Soon thereafter a number of viruses were identified, detected in patients' fecal specimens, and associated with clinical symptoms: during the 1960s, enteric adenoviruses and Norwalk virus (presently defined as noroviruses and belonging, along with the saporovirues, in the *Caliciviridae* family) and in the 1970s rotaviruses, caliciviruses, and astroviruses (*20*). Today, noroviruses are recognized as the most important causes of nonbacterial epidemics of gastroenteritis; rotaviruses account for almost one third of all diarrhea-related deaths in children aged <5 years worldwide; and since 2006, two new safe rotavirus vaccines have been licensed. Feces remains the main clinical sample, and available laboratory diagnostic tests range from isolation of viruses in cell culture to direct visualization of viruses in clinical specimens (e.g., electron microscopy) to detection of viral antigens (e.g., enzyme-linked immunosorbent assay) to detection of viral nucleic acid (e.g., PCR).

Legionnaires Disease

In July 1976, the disease became a household word when approximately 200 American Legion conventioneers in Philadelphia were stricken, resulting in 34 fatalities (*21*). Initial media speculation focused on swine influenza, which had caused an outbreak in Fort Dix, New Jersey, and media excitement earlier in the year. An extensive epidemiologic investigation indicated airborne transmission of an agent in the environment, but the inability of the state and CDC laboratories to identify quickly an infectious etiologic agent intensified media attention and speculation about other sources, including heavy metals or other poisons such as paraquat and even terrorism. During fall 1976, a team of nationally recognized pathologists visited CDC and reviewed clinical findings, autopsy materials, and tissue sections and concluded the causative agent could be a virus or a toxin but not a bacterium, illustrating the pitfalls of using conventional

techniques to identify an unknown, unconventional agent. In December 1976, CDC identified the agent as a bacterium that could not be detected by using ordinary tissue staining (*22*) (Figure 2). Tissues from Guinea pigs inoculated with patient specimens showed small pleomorphic rods by fluorescent antibody staining by using convalescent serum. The bacteria were initially grown in eggs injected with tissue from Guinea pigs and eventually on microbiologic media, allowing production of reasonable amounts of materials for other studies.

The initial reports and presentations by CDC describing the etiologic agent were met with considerable skepticism and disbelief, but the etiology and the name *Legionella pneumophila* became accepted as outbreaks were reported by others. The identification of *L. pneumophila* as a new species of bacteria was determined by using DNA–DNA hybridization (*23*). Today, the genus *Legionella* contains 48 species, 20 of which have been shown to cause human disease.

Outbreaks occurring as early as 1957 were retrospectively associated with serologic evidence of Legionnaires disease (or legionellosis). After *L. pneumophila* was identified and this bacterium was delineated as a common cause of pneumonia, several outbreaks have occured around the world, some as large as 800 cases. Retrospective examples of legionellosis include an outbreak of pneumonia among patients of the St. Elizabeth's Psychiatric Hospital, Washington, D.C., during 1965 with 94 cases and 16 deaths. Another form of this disease was shown in visitors to and employees of the Pontiac, Michigan, health department in 1968 with 144 cases of fever, headache, myalgia, and fatigue without pneumonia, resulting in no fatalities (*24*). In addition to these serologic investigations that used microbiologic analysis of bacteria stored at CDC, an unclassified agent isolated in 1947, was shown to be identical to *L. pneumophila* by serologic, cultural, and DNA relatedness studies. In these situations, the maintaining of large patient specimen collections, serum banks, and culture collections was shown to be of great value.

Although the bacterium is widespread in many freshwater environments, the disease is usually associated with human-made water systems, such as cooling towers, air conditioning, fountains, spa baths, and water supply systems of buildings (including showers). Although culture remains the standard, PCR is increasingly used to detect *Legionella* spp. (*25*). Understanding the modes of transmission and epidemiology of legionellosis has resulted in major changes in construction and maintenance recommendations for municipal, commercial, and residential water systems.

FIGURE 2. Dr. Joseph E. McDade (left), and Dr. Charles C. Shepard, working with a microscope in CDC's leprosy and Rickettsia laboratories in 1977. On January 14, 1977, they isolated the agent that had caused the Legionnaires outbreak

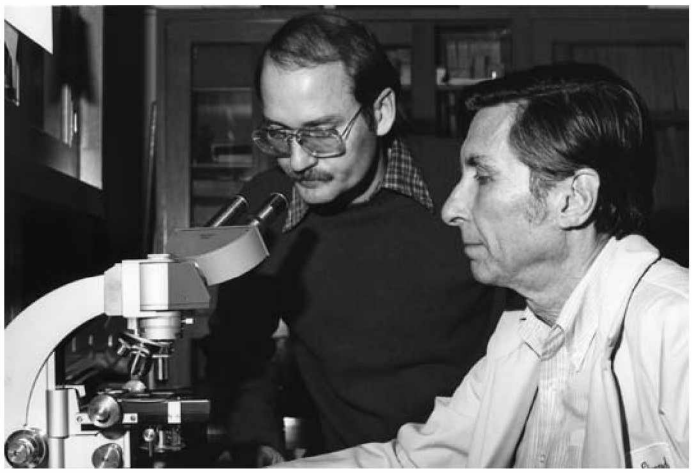

Photo: CDC

Noninfectious Diseases

The inaugural CDC *MMWR* volume was devoted almost exclusively to infectious diseases. Even at the time, however, CDC and other laboratories were engaged in noninfectious disease research that would make major contributions to the identification and prevention of chronic, newborn, and environmental diseases and conditions. Examples include 1) standardizing cholesterol measurements that enabled longitudinal studies to establish the causal link between cholesterol levels and cardiovascular disease (CVD); 2) identifying lead in gasoline as a major source of lead exposure for children and adults; 3) characterizing exposure to tobacco smoke and its toxic constituents in smokers and nonsmokers; and 4) developing methods and providing quality assurance for screening for conditions and diseases of newborns.

CVD remains the leading cause of death in the United States, with reduction of low-density lipoprotein ("bad") cholesterol a major public health priority to prevent CVD and death (*26*) (Figure 3). In 1957, CDC began collaboration with the National Heart, Lung and Blood Institute to develop a standardization program for total cholesterol measurements. The initial program, called the Cooperative Cholesterol Standardization Program, was later expanded to include triglycerides and high-density lipoprotein ("good") cholesterol and renamed the Lipid Standardization Program. These programs had a goal of standardizing lipid and lipoprotein measurements and, ultimately, decreasing deaths and disability from heart disease (*27*). CDC's cholesterol reference method has served as the standard for cholesterol testing for approximately 35 years

FIGURE 3. A laboratorian using a manual method for conducting a cholesterol determination. 1966

Photo: CDC

and was essential to provide the accuracy base for cholesterol measurements in the major epidemiologic studies and clinical trials that established the relationship between cholesterol concentrations and risk for CVD (*28*). In addition to the Lipid Standardization Program, CDC continues to standardize a network of five laboratories that use the CDC accuracy base to calibrate measurement of high-density liproprotein cholesterol, low-density liproprotein cholesterol, and total cholesterol by commercial instrumentation in the clinical laboratories that measure the lipid levels of Americans.

Lead exposure is one of the oldest known environmental and occupational hazards, but not until the early 1970s was relatively low-level exposure recognized to cause neurodevelopmental impairment in children (*29*). Using highly precise and accurate atomic absorption methods, CDC measured blood lead levels in the U.S. population as a component of CDC's National Health and Nutrition Examination Surveys during 1976–1980 (*30*) and identified lead in gasoline as a major exposure source for children and adults. This new and unexpected finding was a major factor in the U.S. Environmental Protection Agency's decision to remove lead from gasoline, an effort that has been cited as one of the most important accomplishments of public health (*31*). Accurate blood lead measurements in the National Health and Nutrition Examination Surveys documented that the removal of lead from gasoline resulted in a >90% decrease in the percentage of children with blood lead levels ≥10 μg/dL, the current level of health concern (*32,33*). These data supported removal of lead from gasoline in industrialized nations around the world, resulting in similar reductions in lead exposure.

Development of methods to quantify approximately 100 addictive and toxic constituents of tobacco products led to an especially sensitive and accurate measurement for serum cotinine to quantify tobacco smoke exposure in smokers and to nonsmokers exposed to secondhand smoke. Evidence that 88% of nonsmokers were exposed to secondhand smoke was used during the early 1990s to justify restricting smoking in public places and in the workplace (*34*). Follow-up of cotinine measurements documented the reduction in average cotinine levels for nonsmokers by approximately 70% (*34*). CDC measurements of addictive and toxic constituents of tobacco products, including tobacco-specific carcinogens, are the major science underpinnings for regulation of tobacco products.

CDC standardizes diagnostic methods for >50 diseases of newborns, ensuring the quality of measurements performed on heel-stick blood spot specimens from >98% of all babies born each year in the United States. Laboratory measurements for early diagnosis usually lead to effective early treatment of many diseases, including congenital hypothyroidism, congenital toxoplasmosis, galactosemia, congenital adrenal hyperplasia, sickle cell disease, maternal HIV infection, cystic fibrosis, fatty acid oxidation disorders, and amino acid disorders.

CDC characterizes exposure of the U.S. population and vulnerable population groups to environmental chemicals known or suspected to cause health problems (*35*). CDC can currently measure 396 environmental chemicals in blood or urine—with future plans to expand to more than 500. Studies of human exposure and health effects particularly benefit from CDC blood and urine measurements of these chemicals. In addition, to bolster emergency response for chemical and radiologic terrorism, CDC has developed capability to measure, in blood or urine, 150 chemical agents and nine radionuclides that are priority terrorism agents. Future plans include expansion of these capabilities, with special focus on measuring additional radionuclides.

The Public Health Laboratory of the Future

The disease triangle is the basic tenet for causation of infectious disease representing the interaction between three entities: environment, pathogen, and host. Chronic diseases are generally caused by the interaction of host factors and the environment, including lifestyle factors and diet, with pathogens sometimes playing a causative role—for example, human papillomavirus linked to cervical cancer and *Helicobacter pylori* linked to the development of duodenal and gastric ulcers and stomach cancer. Advances in laboratory sciences, including informatics and bioinformatics, molecular biology and genomics, nanotechnology and technologies yet to come will facilitate understanding of causation and epidemiology of infectious and chronic diseases that threaten the public's health.

Enormous progress has been made since the central dogma of molecular biology (DNA to RNA to protein) was elucidated some 50 years ago, and revised in 1970 with the discovery of reverse transcription (*36*). Many new "-omics have appeared," including genomics, proteomics, glycomics, metabalomics, and, transcriptomics. A Google search yielded about 60 million results for the term genome (*37*) alone. The development of the PCR, for which Kerry Mullis won a Nobel Prize in 1993, made sequencing the human and other genomes feasible (*38*). Soon, single-molecule DNA sequencing will make it possible to envision whole genomes, including the human genome, to be sequenced in 1 day at a cost of <$1,000 (*39*). Bioinformatics has made it possible to exploit these techniques, generate algorithms, and rapidly analyze complex laboratory and epidemiologic databases to identify virulence factors in infectious diseases and detect biomarkers at the earliest stages when diseases can be reliably predicted and prevented.

The laboratory of the future will build on the work being done today in miniaturization and nanotechnology, considered to be the third industrial revolution. Miniaturization of laboratory instruments at the point-of-care will allow public health workers to obtain patient data in remote places. Ultrasensitive immunosensors and arrays based on nanotechnology will have the ability to quantify protein concentrations at the level below micrograms/deciliter (*40*). Urinary tract infections will be identified at the bedside in remote regions with miniaturized electrochemical biosensors (*41*).

Continued advances in laboratory science and informatics are critically important for all aspects of public health, especially for public health surveillance where informatics is essential for defining the baseline information about human health and for evaluating progress. However, care must be taken that the application of newer laboratory techniques and more sophisticated health informatics introduced for the good of public health do not also bring unintended harm. Society must judge the ethics of implementing the scientifically possible, whether it is the personal risk of the use of nanoparticles or the privacy risk of placing a patient's genome in an electronic record.

Conclusions

Enormous advances have been made in the public health laboratory in the past 50 years, greatly expanding disease knowledge, revolutionizing diagnostic and surveillance relevance and capacity, and facilitating appropriate control strategies. From limited biologic capabilities, today's public health laboratory routinely uses a multitude of molecular technologies and electronic applications. From a small number of laboratories with primarily an infectious disease focus, today's public health laboratory is responsible for emergency preparedness and response, environmental health, food safety, global health, infectious diseases, informatics, laboratory systems and standards, genetics and newborn screening, and research. From a narrow local, state, or national perspective, today's public health laboratories are recognized as essential components of a vital national and global surveillance system. The next 50 years are anticipated to be equally exciting and the young public health practitioners will see and benefit from this progress.

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History of Statistics in Public Health at CDC, 1960–2010: the Rise of Statistical Evidence

Donna F. Stroup, PhD[1]
Rob Lyerla, PhD[2]
[1]*Data for Solutions, Inc., Decatur, Georgia*
[2]*Office of the Global AIDS Coordinator, US Department of State*

Corresponding author: Donna F. Stroup, PhD, Data for Solutions, Inc., Post Office Box 894, Decatur, GA 30031-0894; Telephone: 404-218-0841; Fax: 404-377-9696; E-mail: donnafstroup@dataforsolutions.com.

"A … firm grasp of the statistical method was as essential part of the outfit of the investigator in that field [epidemiology] as was a grounding in bacteriology."—Anonymous, 1913 (1)

Introduction

It is difficult for us to imagine the report of an epidemiologic investigation without at least one 2×2 table, p value, or odds ratio. We now recognize that an understanding of mathematical methods and the use of statistics to assess data in epidemiology and public health are critical for identifying the causes of disease, modes of transmission, appropriate control and prevention measures, and for prioritizing and evaluating activities.

When CDC was established in 1946 (as the Communicable Disease Center), the U.S. Public Health Service borrowed statistical methods developed by Florence Nightingale and Edwin Chadwick, who had applied these techniques to implement sanitary measures in London (*2*). Based on William Farr's use of statistical induction to analyze death rates (*3*), Karl Pearson's creation of goodness-of-fit tests and correlation methods, and Bradford Hill's development of guidelines for establishing causal relationships (*4*), Nightingale employed statistics in her efforts to reform the British military health-care system through the founding of training programs and definition of sound professional standards (*5*).

During the 1950s, CDC's activities emphasized the work of sanitarians and laboratory scientists, and the analytic component of most epidemiologic investigations rarely went beyond descriptive analysis and 2×2 tables. However, with the establishment of the Epidemic Intelligence Service (EIS), rapid response to outbreak investigations, and involvement of mathematical experts, epidemiologic methods advanced (*6*). Case-control studies were used routinely by EIS officers. An investigation of *Staphylococcus* in a newborn nursery was the first CDC report to include a chi-square statistic and a p value (CDC, unpublished data, 1957). By the middle of the decade, an early dose-response analysis was included in an investigation of hepatitis in a housing project (CDC, unpublished data, 1956).

The 1960s

With the acquisition of *MMWR* in 1961 under Alexander Langmuir's leadership, CDC had a vehicle for influencing the practice of biostatistics. Langmuir's training under Wade Hampton Frost, the first professor of epidemiology in the United States at the Johns Hopkins University School of Hygiene and Public Health, led to Langmuir's emphasis on quantitative foundations for public health and the need to link data acquisition with practical application through the practice of public health surveillance (*7*).

During this decade, the first *t* test in an epidemic-assistance investigation (Epi-Aid) is found in Carl Norden's report of infectious mononucleosis in Kentucky (CDC, unpublished data, 1963). The first pie chart appears in James Bryan and Ron Roberto's Epi-Aid for suspected poliomyelitis in the Marshall Islands (CDC, unpublished data, 1963). During this period, the vast majority of requests for Epi-Aids collected data through convenience survey methods or used existing surveillance data. In only two of 502 Epi-Aids was the method of randomization reported. Calculations were restricted to those that could be done by hand or later on programmable calculators (Figure 1). Eventually, however, surveillance and other data analyses used mainframe computers and the punched card throughout the late 1960s.

The 1970s

In 1970, the Communicable Disease Center's name changed to the Center for Disease Control. Beyond semantics, this represented a broadening of the mission beyond communicable diseases. In 1971, the National Center for Health Statistics (not yet part of CDC) conducted the first National Health Assessment and Nutrition Examination Survey (NHANES). The National Institute for Occupational Safety and Health

FIGURE 1. Statistician at CDC using MonroMatic desktop calculator, Model 8N-213. circa 1958

Photo: CDC

joined CDC in 1973 and brought use of methods for noninfectious conditions, such as large population-based studies.

This expansion of activity to environmental and occupational problems brought expanded opportunities for the contribution of statistical and engineering methods to public health. One example is the use of NHANES data combined with data on lead in gasoline from the U.S. Environmental Protection Agency to develop a model to predict human blood lead levels (*8*). The results were used to provide evidence that subsequently led to a ban on the use of lead in gasoline in the United States.

In 1974, CDC assumed leadership of a major national immunization campaign. Although the theory behind herd immunity was developed during the 1920s, the development of vaccines coupled with advances in mathematical modeling in epidemiology found a new synergy in a paper written in 1971 (*9*). Four years earlier, in 1967, the World Health Organization had declared its intent to eradicate smallpox within 10 years, and the U.S. Public Health Service had declared its intent to eliminate measles from the United States within 1 year (*10*). Both of these tasks were theoretically to be achieved by the induction of herd immunity with vaccines.

The year 1976 saw the beginning of flexible computing in public health. To address the swine flu crisis (*11*), an auditorium at CDC was filled with epidemiologists and a Digital Equipment PDP 11 minicomputer the size of a large refrigerator. A program called SOCRATES, written in FORTRAN, allowed an epidemiologist to define questions, enter data, and summarize the results in tabular form without the aid of a programmer or a trip across campus to a mainframe computer. The SOCRATES program later formed the basis of another program, the Epidemiologic Analysis System, which was an early forerunner of Epi Info™, a suite of lightweight software tools for use in field epidemiology first released by CDC in 1985 (see below).

The 1980s

In the 1980s, public health saw an expansion of emphasis on statistical methods and more statistical sophistication among epidemiologists and analysts. The computer-punched card was gradually replaced as the primary means for data storage by magnetic tape, as better computers became available (Figure 2). Punched cards were still commonly used for data entry and programming at CDC until the mid-1980s, when the combination of lower-cost magnetic disk storage and affordable interactive terminals on less expensive minicomputers made punched cards obsolete. However, their influence persists through many standard conventions and file formats. For example, the terminals that replaced the mainframe card readers displayed 80 columns of text, the same amount of space on the punched card.

The first report in *MMWR* containing results from a logistic regression model appeared in 1982, only 3 years after the software package BMDP provided the LOGIT routine as part of its software (*12*). In this investigation of typhoid fever in Michigan, the model was unable to identify risk associated with any food item because of a small number of cases and little variation in food-consumption patterns. Since this first use, logistic regression has become a standard technique in public health and has contributed to policy formulation in

FIGURE 2. Computer workstation at CDC, 1980s

Photo: CDC

many areas. For example, the results from a logistic regression analysis were used to implement a requirement that tobacco-control programs should include opportunities for community participation and interaction for maximal impact. (*13*).

In the early 1980s, CDC launched a major case-control study as part of the nascent investigation of human immunodeficiency virus (HIV)/acquired immunodeficiency syndrome (AIDS) (*14*), which provided a platform for development of new statistical methods for surveillance and estimation of disease incubation periods (*15*). A major challenge for HIV/AIDS surveillance was poor data quality due to underreporting, reporting delay (*16*), and risk redistribution (*17*). To address these problems, statistical scientists adapted methods from correlation analysis (*18*) and developed a technique known as back-calculation (*19*).

Back-calculation uses the number of AIDS cases diagnosed per month or calendar quarter (which can be estimated from AIDS surveillance data) and the probability distribution of the incubation period (the time from HIV infection to diagnosis of AIDS) to estimate the number of persons infected with HIV. This incubation distribution must be estimated from cohort studies. On the basis of these data, back-calculation methods provide estimates of the number of persons infected with HIV during each month or calendar quarter necessary to account for the number of persons in whom AIDS has been diagnosed during those same periods. The number of persons in whom AIDS will be diagnosed in the future can then be projected from the estimated HIV epidemic curve and the incubation period distribution (*20*).

The back calculation method proved useful in navigating two major changes in the way HIV/AIDS surveillance was conducted. One was a 1993 change in the surveillance case definition for AIDS to include all HIV-infected persons who have <200 CD4+ T-lymphocytes/μL or a CD4+ T-lymphocyte percentage of total lymphocytes <14, or in whom pulmonary tuberculosis, invasive cervical cancer, or recurrent pneumonia has been diagnosed (*21*). The other was the development and widespread use of pharmacotherapy (zidovudine) (*22*). These and other statistical challenges in HIV/AIDS surveillance illustrated well the ability of statistical methods to respond to developing public health problems.

During the mid-1980s, with the increasing availability of microcomputers, CDC epidemiologists first began using computers during field investigations, but no user-friendly software existed for the purpose. To remedy this problem, in the early 1980s, CDC began development of Epi Info, a general-purpose computer program that could be used for epidemic investigations and surveillance (Table). Early versions of Epi Info were used in field investigations on large "luggable" computers (*23*) (Figure 3). The widespread distribution of Epi Info and the responsiveness of its developers to the needs of epidemiologists in the field drove the application of statistical methods in field investigations throughout the world (*24*). A recent search of MEDLINE found >23,000 citations mentioning Epi Info in the peer-reviewed literature. Add to this countless other citations in reports not indexed, and the impact of its development on the field of statistics is apparent. In addition, Epi Info aided in early efforts to coordinate surveillance activities to reduce the workload of state health departments (*25*).

During this period, statistical methods for surveillance also advanced. The availability of methods of forecasting by using time series methods augmented previous regression results (*26,27*). An investigation in response to food poisoning in Peru was the first documented field investigation to implement a time series analysis (CDC, unpublished data, 1986). Use of these methods, developed during the 1920s, was aided by the availability of computers that allowed computations to be conducted in a reasonable amount of time.

More broadly, methods were developed to investigate changes in patterns of surveillance data to aid in epidemic detection and control (*28*). This development was further aided in 1987, when the National Center for Health Statistics became part of CDC and brought its expertise in vital statistics and surveys (*29*).

The 1990s

Innovations continued during the 1990s in such areas as the detection of statistical aberrations, and changes in patterns of data reported over time (*30–33*). A 1988 Symposium on Statistics in Surveillance (*34*) became the foundation for ongoing CDC symposia on the statistics of cluster investigations (*35*), statistics for rare events and small areas (*36*), statistics as a basis for public health decisions (*37*), emerging statistical issues (*38*), complicated designs and data structures (*39*), methods for decisions in uncertainty (*40*), methods for addressing health inequities (*41*), and use of multisource data (*42*). Over time, these symposia were accompanied by short courses to educate the public health community about statistical methods (*43*). In addition, CDC began giving awards for outstanding statistical work that had public health impact (Figure 4).

Despite considerable achievements in reducing smoking prevalence as the 20th century closed, tobacco use remained responsible for one of every five U.S. deaths. In 1999, CDC's Office on Smoking and Health created the National Tobacco Control Program to encourage coordinated efforts to reduce tobacco-related diseases and deaths (*44*). The National Youth Tobacco Survey measured the tobacco-related beliefs, attitudes,

TABLE. Examples of software systems developed by CDC in the 1980s and 1990s

Sofware system name	Primary use	Reference
IDEAS (Interactive Data Entry and Analysis System)	Support hospitals' participation in CDC's nosocomial infection surveillance activities	Horan TC, White JW, Jarvis WR, et al. Nosocomial infection surveillance, 1984. MMWR 1986;35(No. SS-1).
SAMEC (Smoking-Attributable Mortality and Economic Costs)	Allow states and local areas to estimate the impact of smoking-attributable illness and mortality	CDC. State-specific estimates of smoking-attributable mortality and years of potential life lost—United States, 1985. MMWR 1988;37:689–93.
Software for Congenital Syphilis Surveillance	Assist states in reporting cases of congenital syphilis	Dunn RA, Webster LA, Nakashima AK, Sylvester GC, Surveillance for geographic and secular trends in congenital syphilis—United States, 1983–1991, MMWR 1993;42(No. SS-6).
ARDI (Alcohol-Related Disease Impact)	Estimate the impact of alcohol consumption	CDC. Deaths and hospitalizations from chronic liver disease and cirrhosis—United States, 1980–1989. MMWR 1993;41:969–73. CDC. Alcohol-Related Disease Impact (ARDI). Available at http://apps.nccd.cdc.gov/ardi/homepage.aspx.
SURVTB	Support state health departments in TB case surveillance and prevention	CDC. Expanded tuberculosis surveillance and tuberculosis morbidity—United States, 1993. MMWR 1994;43:361–6.
STELLAR (Systematic Tracking of Elevated Lead Levels & Remediation)	Support state activities in prevention of elevated blood lead levels	CDC. State activities for prevention of lead. MMWR 1993;42:165,171–2.
PHLIS (Public Health Laboratory Surveillance System)	Support reporting from state public health laboratories	Bean NH, Martin SM, Bradford H, Jr. PHLIS: an electronic system for reporting public health data from remote sites. Am J Public Health 1992;82:1273–6.
Epi Info	Support data collection and analysis from field investigations; to support state surveillance activities	Dean AG, Dean JA, Burton AH, Dicker RC. Epi Info: a general-purpose microcomputer program for public health information systems. Am J Prev Med 1991;7:178–82.

FIGURE 3. "Luggable" Osborne computer, circa 1981

Photo: CDC

and behaviors of youth and was the first to gather data from both high school and middle school students. Findings were used to design strategies for youth-focused antitobacco campaigns (*45*). In 1994, economic methods were used to measure smoking-attributable costs (*46*).

In 1992, Anderson and May published *Infectious Disease of Humans* (*47*), documenting their work in mathematical modeling transmission of infectious diseases, which was critically important to understanding the ongoing work in fighting the global HIV epidemic, as well as malaria and tuberculosis. Subsequent work on modeling diseases has been used to monitor and model the impact of influenza outbreaks. During the 1990s, laboratory techniques improved enough so that strains of viruses could be mapped and links made to the epidemiologic investigation.

The 2000s

Although today the consequences of unhealthy dietary choices, sedentary lifestyles, and "supersized" food portions are familiar, during the late 1990s, their potential for harm was underestimated. Research published in 1999 documented the nation's rapidly increasing obesity rates in all U.S. states, regions, and demographic groups (*48*). In 2001, Congress appropriated $125 million for CDC to develop a national media campaign to change children's health behaviors. CDC responded through VERB, an innovative and expansive campaign based on behavioral science theory and contemporary principles of marketing, which produced measurable positive results (*49*). Once again, CDC epidemiologists were using statistical analytic methods that had previously been used in other disciplines. For example, Bayesian methods used by businesses and marketers to model personal and community decision making preferences (*50*) or cluster analysis and marketing segmentation methods were being used to inform health intervention and evaluation of health programs (*51*).

FIGURE 4. CDC's Statistical Achievement Ceremony 1993: Award for statistical methods to Investigation of 2,3,7,8-tetrachorodibeno-*p*-dioxin half-life heterogeneity in Veterans of Operation Ranch Hand. Claire V. Broome (presenter), James Pirkle, Samuel Caudill, and Mitchell Gail (National Institutes of Health)

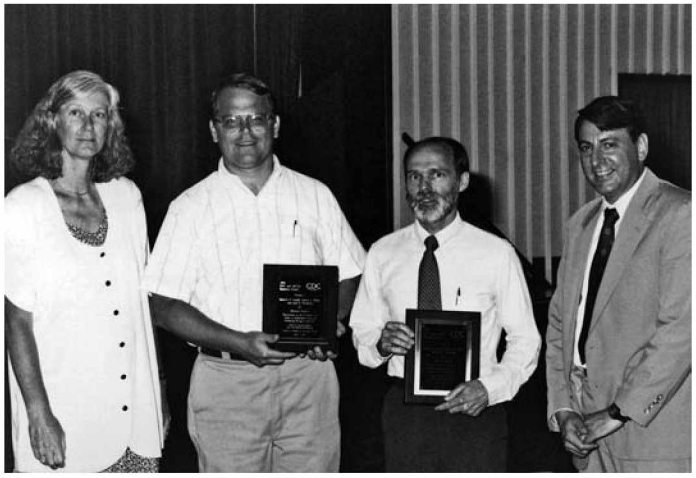

Photo: CDC

Statistical methods in longitudinal analysis and mixed models used commonly in social research also contributed to the evaluation of results (*52*). Likewise, a method developed in 1896 for studies in biological sciences, capture-recapture analysis, was adapted for evaluating surveillance systems (*53,54*). This method facilitated the estimation of total number of cases from two surveillance sources, each of which might not be complete.

In response to the terrorism events of 2001, statisticians began to develop methods for use in defense and national security (*55*). The rise of spatial statistics and geographic information systems meant that epidemiologists could better map prevalence data to suggest gaps in response or impact of disease or injury (*56*). Economic data could be mapped for use in cost-effectiveness studies, and overlaying data types (prevalence, economic costs, demographics) could be used for better decision making and for evaluation of programs. Mapping the cholera outbreak in John Snow's time seemed to have come full circle.

Many of the techniques of spatial analysis depend on statistical measures and methods, including univariate statistical measures and directional analysis (*57*). Additionally, statistical methods have been developed to address the specific needs of spatial datasets. The nature of these extensions differs from the ways in which multivariate statistics are derived from their univariate counterparts because of concepts of distance, direction, contiguity, and scale. For example, classical hypothesis testing and inferential procedures might not be appropriate for spatial problems because the datasets do not satisfy classical independence or distributional requirements or because the sampling frame may be unknown or poorly specified.

The Future of Statistics

In the future, epidemiologists will continue to pursue new statistical techniques that can increase the impact of their analyses on public health. For example, the coming decades might bring innovations in new data collection modalities (e.g., hand-held data collection methods, cellular phones) and methods needed to evaluate new public health and medical interventions, and they will all be packed into a shrinking global village. A large body of methods (e.g., canonical correlations, factor analyses, exposure assessment, nonparametric statistics, infectious disease modeling) can be brought to bear on new public health problems. However, the use of these new technologies also comes with challenges.

For example, the introduction of parallel sequencing technologies (*58*) has led to an exponential increase in the amount of available DNA sequence information for epidemiologic investigations. Because sequence data are now produced faster than they can be meaningfully analyzed, new approaches to the analysis of this information is one of the most important recent challenges for epidemiologists, bioinformaticians, and statisticians. Beyond methods to carefully sample and organize the massive amount of data, challenges include development of quantitative methods and models to estimate errors for the various sequencing platforms; algorithms and mathematical estimates of the reliability of genomes assembled from short-gapped reads; approaches to distinguish sequence-determination errors from biological polymorphism and mutation; and means to distinguish among multiple genomes within a single dataset, particularly when the relative sizes of those different genomes vastly differ.

Challenges especially relevant to the area of biodetection include development of models for rapid identification of the differences between the genomes of individuals of a species and for distinguishing between naturally occurring biological heterogeneity and newly emerged or artificially produced pathogenic sequences in complex samples. Mathematical models and methods to estimate the significance of genomic variability currently exist, and the use of these models and methods will increase as they become easier to use. Nanotechnology, the understanding and control of matter at dimensions of roughly 1–100 nanometers (10^{-9} meter), where unique phenomena enable novel applications, presents specific challenges to statistical methods: in understanding high variation in experimental results, in developing sampling plans to model the nanofabrication process efficiently, and in helping to improve low-quality and unpredictable product reliability. As they have during the past 50 years, in the coming decades statistical methods will play a major role in strengthening the evidence base for decisions affecting the well-being of communities.

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Changing Methods of NCHS Surveys: 1960–2010 and Beyond

Monroe G. Sirken, PhD[1]
Rosemarie Hirsch, MD[2]
William Mosher, PhD[3]
Chris Moriarity, PhD[4]
Nancy Sonnenfeld, PhD[5]

[1]*Office of the Director, National Center for Health Statistics, CDC, Hyattsville, Maryland*
[2]*Division of Health and Nutrition Examination Surveys, National Center for Health Statistics, CDC, Hyattsville, Maryland*
[3]*Division of Vital Statistics, National Center for Health Statistics, CDC, Hyattsville, Maryland*
[4]*Division of Health Interview Statistics, National Center for Health Statistics, CDC, Hyattsville, Maryland*
[5]*Division of Health Care Statistics, National Center for Health Statistics, CDC, Hyattsville, Maryland*

Corresponding author: Monroe G. Sirken, PhD, 3114 Gracefield Road, Apt. 405, Silver Spring, MD 20904; Telephone: 301-572-5767; E-mail: mgsirken@aol.com.

Introduction

The year 2011 marks the 50th anniversary of CDC's publication of *MMWR*. It also marks the 24th anniversary of the National Center for Health Statistics (NCHS) joining CDC in 1987. One of NCHS's greatest contributions to public health has been in surveys and survey methodology. Today, more than 50 years after NCHS was formed in 1960, NCHS continues to conduct some of the leading health surveys of the United States. This report describes some of the many innovations and changes in NCHS survey methods during the past 50 years and briefly previews how the methods might change in the future.

A Brief History of NCHS and NCHS Health Surveys

NCHS is the designated federal statistical agency for compiling, analyzing, and disseminating national health and vital statistics and for monitoring the health of and health care in the nation (http://www.cdc.gov/nchs/about/mission.htm). NCHS was established in 1960 with the merger of two U.S. Public Health Service agencies, the National Office of Vital Statistics and the National Health Survey Program (NHS). The National Office of Vital Statistics, which had been part of the Public Health Service since transferring from the U.S. Bureau of the Census in 1946, was responsible for producing national vital statistics on births, deaths, fetal deaths, marriages, and divorces. NHS had been created in 1956 after passage of the Public Health Service Act. Section 306 of the Act authorizes NCHS to collect national statistics on 1) the extent of illness and disability; 2) the impact of illness and disability on the economy; 3) environmental, social, and other health hazards; 4) determinants of health; 5) health resources; 6) use of health-care resources; 7) health-care costs and financing; and 8) family formation, growth, and dissolution. The Act also directs NCHS to conduct research to develop and improve methods of health surveys.

Since its founding in 1960, NCHS has conducted 15 distinct major surveys (http://www.cdc.gov/nchs) (Table 1). The National Health Interview Survey (NHIS) and the National Health Examination Survey (NHES) were started as part of NHS in 1957 and 1959, respectively, and continued after NCHS was established in 1960. The National Health and Nutrition Examination Survey (NHANES) replaced the NHES in 1971. The National Survey of Family Growth (NSFG) was started in 1973, and the first of eight components of the National Health Care Surveys (NHCS) was started in 1965. The vital records follow-back surveys linked to national samples of birth and death records have been discontinued and two random digit-dialed telephone surveys—the National Immunization Survey and the State and Local Area Integrated Telephone Survey—have been introduced.

Examples of Major Innovations in NCHS Survey Methods

Innovations in NCHS survey methods during the past 50 years have been driven largely by advances in information technology and in the statistical, behavioral, and cognitive sciences. One way to examine these innovations is to categorize them by the six stages of the survey measurement process to which they apply: sample design, questionnaire design, data collection, data processing, data dissemination, and data analysis. Six examples of innovations in NCHS surveys are presented, one innovation for each measurement stage.

TABLE. Principal surveys conducted by the National Center for Health Statistics

Survey*	Periodicity	Year established	Most recent active year
Household and examination surveys			
National Health Interview Survey (NHIS)	Annually	1957	2011
National Health Examination Survey (NHES)	Periodically	1959	1970
National Health and Nutrition Examination Survey (NHANES)	Annually since 1999	1971	2011
National Survey of Family Growth (NSFG)	Annually since 2006	1973	2011
Vital record–linked surveys			
National Mortality Follow-back Survey (NMFS)	Periodically	1961	1995
National Natality Follow-back Survey (NNFS)	Periodically	1963	1988
Health-care surveys			
National Hospital Discharge Survey (NHDS)	Annually	1965	2010
National Ambulatory Medical Care Survey (NAMCS)	Annually since 1989	1973	2011
National Nursing Home Survey (NNHS)	Periodically	1973	2004
National Home and Hospice Care Survey (NHHCS)	Periodically	1992	2007
National Hospital Ambulatory Medical Care Survey (NHAMCS)	Annually	1992	2011
National Survey of Ambulatory Surgery (NSAS)	Periodically	1994	2006
National Survey of Residential Care Facilities (NSRCF)	Periodically	1989	2010
National Hospital Care Survey	Annually	2011	2011
Random-digit dialed telephone surveys			
National Immunization Survey (NIS)†	Annually	1994	2011
State and Local Area Integrated Telephone Survey (SLAITS)	Annually	1997	2011

* See Reference 1 for survey descriptions.
† Conducted with the National Center for Immunizations and Respiratory Diseases.

Stage 1. Sample Design: Network Sampling

Network sampling was introduced by NCHS staff during the 1970s to improve the precision of sample surveys of rare and elusive populations (*2*). Network sampling also was applied in the 1977 NHIS to estimate the national prevalence of diabetes (*3*). Subsequently, it was used in the National Ambulatory Medical Care Survey (NAMCS) to transform estimates of the numbers of physician office visits into estimates of the number of persons who visited physicians' offices (*4*) and to transform estimates of the number of practicing physicians into estimates of the numbers of physician practices (*5*).

Stage 2. Questionnaire Design: The Cognitive Research Laboratory

A cognitive research laboratory is a workplace for designing and testing survey questionnaires. Cognitive interviewing methods are used to detect and eliminate cognitive problems that respondents have in answering survey questions (*6*). The NCHS Questionnaire Design Research Laboratory (QDRL) was established in 1985. It was the first permanent cognitive research laboratory in a statistical agency or elsewhere, and it served as a model for cognitively testing survey questionnaires that has been adapted by many survey research organizations in the government and private sectors in this country or elsewhere.

In 2002, the QDRL initiated the development of Q-Bank, a computerized database of cognitively tested questions. Under the QDRL's management, the Q-Bank serves as the federal interagency repository of cognitively tested survey questions (http://www.cdc.gov/qbank/home.aspx).

Stage 3. Data Collection: Administrative Record Linkage

Formally established in the late 1990s, the NCHS Administrative Record Linkage Program links NCHS data files with administrative record files (http://www.cdc.gov/nchs/data_access/data_linkage_activities.htm). However, some NCHS data files have been linked to some administrative record files since the early and mid-1980s. The Program expanded the scope of NCHS surveys and increased their analytic power to examine factors affecting disability, chronic diseases, health-care use, and illnesses and death (http://www.cdc.nchs/data_access/data_linkage _activities.htm). The program links NCHS survey files with death records from the National Death Index; air monitoring data from the U.S. Environmental Protection Agency; Medicare enrollment and claims data from the Centers for Medicare and Medicaid Services; and Retirement, Survivor, and Disability Insurance and Supplemental Social Security Income benefit data from the Social Security Administration. A pilot study is under

way to link NHANES data to state administrative records for Supplemental Nutrition Assistance Program (formerly called the Food Stamp Program) and Temporary Assistance for Needy Families.

Stage 4. Data Processing: Multiple Imputation for Missing Data

Multiple imputation is a model-based technique for imputing values of missing data in which missing values are independently imputed two or more times (*7*). Thus, multiple imputation retains the advantages of single imputation by decreasing bias due to missing data (if the imputation model is valid) and allowing data analysts to obtain valid assessments of variability due to imputation. NHANES III (1988–1994) became one of the first large-scale multiple imputation applications to impute values of missing data on several variables in a large public-use data file. NHIS has used multiple imputation annually since 1997 to impute missing values of personal earnings and family income.

Stage 5. Data Dissemination by Remote Access: The Research Data Center

In 1988, NCHS established the Research Data Center (RDC) (http://www.cdc.gov/rdc) to provide off-site researchers access to NCHS restricted data files while maintaining data confidentiality. The Research Data Center was modeled after the Census Bureau's research data centers. Remote access allows a researcher to run statistical programs against an analytic data set created specifically for the approved use. After the output has been checked for disclosure risk by an NCHS automated system, it is sent to the researcher. This automated tool for remote access is unique in the federal statistical system and is a key element in expanding access to data for the public health research community.

Stage 6. Data Analysis: Secondary Analyses of Survey Data

During the 1960s, analyses of NCHS survey data were limited largely to descriptive statistics. However, recent advances in statistical methods and computer software appropriate for secondary analyses of data collected in complex sample surveys has greatly expanded the use of NCHS survey data for research purposes. For example, NCHS staff pooled 3 NHIS data years, 1998–2000, to bridge the changes in the classification of race from single-race reporting to multiple-race reporting before and after the 2000 population census (*8*). Advances in statistical methods and computer software have provided analysts of NCHS public-use data files with capabilities to address important issues in cancer research (*9*).

Examples of Survey-Specific Methodology Changes

The founders of NCHS introduced four complementary surveys, NHIS, NHANES, NHCS, and NSFG. They viewed these four surveys as collectively capable of producing the wide range of national health statistics authorized by NCHS' legislation. The examples discussed below illustrate how methods of these surveys have changed during the past 50 years in response to the evolving needs for health statistics.

The National Health Interview Survey

NHIS, the principal source of national information about the health of the U.S. civilian population living in households (*10*), annually collects information through personal interviews on the reported incidence of acute illness and injuries, prevalence of chronic conditions and impairments, extent of disability, use of health services, and in-depth demographic and socioeconomic data. Collection of these data allows continuing monitoring of the nation's health (http://www.cdc.gov/nchs/nhis.htm).

Questionnaire Revisions

The NHIS household questionnaire has undergone revision approximately every 10 years, reflecting changes in health measurements, new concepts of health and disease, and evolving factors associated with illness and health. Comparisons of early with later NHIS questionnaires demonstrate an evolution of perspectives, including 1) shifting from an emphasis on detailed medical-care use to general access to and use of health-care services, health behaviors, and perceived health status; 2) changing from focusing exclusively on the family unit to including questions about both family and randomly selected sample persons' (adults and children) health characteristics, along with requiring self-response from the selected adult; 3) moving from a paradigm of individual body systems to a more holistic health approach; and 4) recognizing the need to address health disparities by collecting information for as many minority populations as possible within the constraints of the sample size.

Changes in survey questions have reflected societal changes in the understanding of health and methodologic refinements in ways to address issues of importance, such as proxy responses, recall periods, and definitions of health concepts. In addition to the evolution in concepts and the refinement of key measurements, the NHIS has adapted to changing methods,

moving from pencil and paper administration of the survey to Computer Assisted Personal Interviewing, which when adopted in 1997, increased the flexibility of the instrument and the quality of the resulting data.

Decennial Sample Redesigns

The NHIS household sample has been redesigned after each Population Census to reflect changes in the size and distribution of the national population. The redesign after the 1980 Census also included an important change in the household sampling frame. This change enabled NCHS to analyze data in greater geographic detail; link NHIS files with administrative records; and use NHIS address listings as sampling frames for population surveys, including the NCHS's NSFG, and the Medical Expenditure Panel Survey conducted by the Agency for Health Care Research and Quality (*11*).

The National Health and Nutrition Examination Survey

NHANES collects data on the health and nutritional status of the civilian noninstitutionalized U.S. population through physical examinations and laboratory tests conducted by trained medical personnel in mobile medical centers. NHANES enables assessment of diagnosed and undiagnosed health conditions (*12–14*). Chronic disease, health and risk factor status, infectious disease, oral health, nutrition, environmental health, and genetic data are collected (http://www.cdc.gov/nchs/nhanes.htm).

NHANES Web Tutorial

After NHANES data were made accessible on the NCHS website in 1998 and personal computer–based statistical software became available, the NHANES user base dramatically increased and diversified. In 2005, the NHANES Web Tutorial (NWT) was developed to overcome analytic barriers and promote broader and more proficient use of NHANES data (http://www.cdc.gov/nchs/tutorials/). It was the first NCHS Web tutorial developed and was a collaboration among research analysts, statisticians and programmers, information technology specialists, instructional designers, and science writers.

NWT is a self-guided, distance-based, multimedia interactive learning tool instructing NHANES users how to 1) efficiently locate pertinent information on the NCHS website; 2) quickly retrieve NHANES data files and variables to prepare an analytic dataset; and 3) correctly conduct statistical analyses with appropriate attention to the nuances of NHANES data, given its complex sample design, weighting requirements, and data structure. The tutorial offers analysis tracks in SAS Survey Procedures, SUDAAN, and Stata. It is a textbook of best practices for analyzing NHANES data. It is part of the accredited CDC online learning courses and has been used in several graduate-level university programs. The NWT allows 24/7 data and analysis assistance and has reduced the timeframe for NHANES analysis proficiency from 3–4 months to 3–4 weeks for new staff. Because of the success of the initial NWT, five additional tutorials (environmental health; NHANES I, II, and III supplemental tutorials; and a full dietary tutorial) have been developed, and a sixth (physical activity) is being developed.

Community-Level Health Examination Statistics

Although NHANES serves the health examination data needs on a national level, no comparable program is available for states, local communities, or special populations. To address these gaps, NHANES provides local areas with technical expertise to conduct their own health examination surveys. For example, two projects funded by interested subnational communities have been undertaken. In 2003–2004, NHANES helped the New York City Department of Health and Mental Hygiene successfully conduct the first New York City HANES by using comparable NHANES data collection and information technology methods for selected conditions, such as diabetes, high blood pressure, high cholesterol, and depression (*15,16*). During 2008–2009, NHANES helped Oregon prepare for a landmark, statewide study of health and access to care using similar measures.

These projects stimulated another initiative currently in the evaluation stage that, if successful, might offer a way to obtain community-level estimates nested within future NHANES redesigns for large counties such as Los Angeles County, California, that are part of NHANES sample every year. A special dataset comprising information collected from NHANES participants in Los Angeles County during 1999–2004 was created for this evaluation study (*17*).

The National Survey of Family Growth

NSFG is based on in-person interviews with national samples of men and women 15–44 years of age in the household population of the United States. NSFG collects data on marriage and divorce, sexual activity, infertility, pregnancy outcomes, contraceptive use, and reproductive health (*18,19*). These data help to explain trends and differences in birth and pregnancy rates, reproductive health, and family formation (http://www.cdc.gov/nchs/nsfg.htm).

Audio Computer Assisted Interviewing

When NSFG began during the 1970s, it focused on contraceptive use, infertility, and pregnancy among ever-married women because a relatively small percentage of births were to

unmarried women (*20*). However, as the percentage of births to unmarried women increased (to 18% in 1980 and 39% in 2006 [*20*]), collecting a wider range of sensitive data became more important. To do this, in 1993, NCHS began to collect part of the NSFG interview using Audio Computer Assisted Survey Interviewing (ACASI). ACASI is a means of collecting sensitive information in face-to-face interviews in a way that respects the privacy of respondents and encourages complete and accurate reporting of sensitive behaviors. In ACASI, the respondent uses a laptop computer to read the questions while listening to them through headphones and then enters his or her responses directly into the computer. The interviewer does not see or hear the questions or the answers. This method gives the respondent greater privacy, and it yields more complete reporting of sensitive behaviors than does a paper and pencil questionnaire (*21*). In the 1995 NSFG, ACASI was used primarily to collect data on pregnancy outcomes, but in 2002, the ACASI section of the questionnaire was expanded to collect data on behaviors that increase the risk for HIV and other sexually transmitted infections, including male–male sex, numbers of sex partners, and drug use (*22–24*).

When NSFG changed from periodic to continuous data collection in 2006, collecting real-time administrative data about the survey data collection process became increasingly important to manage the survey. Hence, NSFG began to routinely collect data about the data collection process, called paradata, including the times of day interviews were conducted, length of interviews, and number of attempts to complete interviews. The availability and use of paradata with a 1-day lag between field actions and receipt of the paradata are helping NSFG control both the costs and quality of data collection (*18,25*). The use of paradata for survey management and cost control is in its early developmental stages, and much more remains to be learned about using the paradata to control survey costs, improve data quality, and maximize response rates (*18,25*).

The National Health Care Surveys

The National Health Care Surveys, a family of national surveys of patient encounters with health-care providers in different settings (Table), collects data directly from health-care providers on patients' diagnoses and treatments and on services provided to patients. These surveys also collect information about the health providers. The data are used to assess national patterns in the use, payment, organization, quality, and delivery of health-care services (http://www.cdc.gov/nchs/nhcs.htm).

Survey Integration

As a consequence of introducing new surveys whenever new settings for delivering health services emerge, NHCS has conducted eight distinct and independent provider surveys since 2004. Reducing the number of distinct surveys while retaining the capability of surveying all providers is simplifying planning, making the surveys easier to conduct, and potentially lowering survey costs.

For example, the National Hospital Ambulatory Medical Care Survey (NHAMCS) was initially fielded in 1992 and collects information about patients seen in emergency and outpatient departments of hospitals. The National Survey of Ambulatory Surgery (NSAS) was initially fielded in 1994–1996 and collects information about surgical procedures performed in freestanding and hospital-based ambulatory surgery centers. Initially, NHAMCS and NSAS were independently designed. After a feasibility study demonstrated a cost-effective way to integrate the NSAS and NHAMCS sample designs and data collection methods without loss of data quality, NSAS was combined with the NHAMCS beginning in 2009. The vast majority of freestanding surgery centers were selected from within the NHAMCS primary sampling units, and hospital-based ambulatory surgery centers were selected from hospitals already included in NHAMCS. Information about surgical encounters and patients' procedures was collected by using the same data collection form in both freestanding and ambulatory settings, and data collection forms and methods were standardized with NHAMCS's outpatient department patient record forms.

The increasing use of the electronic medical record system will be a key issue in designing NHCS in the future as increasingly more health-care providers adopt this technology. NHCS has been collecting information about the use of electronic medical records in virtually all of its health-care provider surveys (http://www.cdc.gov/nchs/data/hestat/emr_ehr/emr_ehr.htm). At the present time, gathering national data solely from electronic sources would yield highly unrepresentative estimates. NCHS, however, recognizes that it must prepare for a future in which data may be gathered mainly from electronic systems. Many methodologic problems remain to be addressed. These include identifying the range of data available electronically, defining the items of interest, defining the properties of these data (including their levels of completeness and accuracy compared with conventional paper medical records), developing methods to securely transfer large volumes of confidential data electronically in a manner acceptable to health-care providers surveyed, and developing methods to combine data from disparate noninteroperable systems to produce usable data files.

Future Directions of NCHS' Survey Methods Research Program

Changes in NCHS survey methods will depend on the vigor, rigor and imagination of its survey methods research program in maintaining the statistical standards of the Center's surveys, while also developing and applying innovative survey methods to meet the ever changing needs for health statistics. The survey methods research program is an NCHS-wide effort but is one of the primary missions of the Office of Research and Methodology (ORM). The principal domains of the NCHS program are as follows: short-term and long-term research oriented to NCHS' mission and basic survey research oriented to the future data needs of the Federal Statistical System. However, the boundaries between domains are porous, and the findings of research projects in one domain often lead to new research projects in other domains.

Mission-Oriented Survey Research

Short-term mission-oriented research responds to the ongoing programming needs of an NCHS survey, whether it is NHIS, NHANES, NSFG, or NHCS, and it is usually conducted by the Survey Division's staff and often with ORM support. Examples of ongoing short-term mission-oriented survey research projects are as follows: NHIS post 2010 Census sample redesign, NHANES Web tutorials, NSFG's ACASI, and NHCS's integration of the sample designs of NHAMCS, NSAS, and other health-provider surveys.

Long-term mission-oriented research anticipates the future programmatic needs of NCHS surveys. Examples of possible future long-term mission-oriented survey research projects are as follows: integrating the sample designs of NCHS population and provider surveys, developing analytic methods to assess the health effects of social networks in NCHS population surveys, and assessing the World-Wide Web and the Internet as potential sampling frames and data-collection modes for NCHS surveys.

Basic Survey Research

NCHS collaborates with other federal agencies in conducting basic interdisciplinary surveys oriented to the future data needs of the Federal Statistical System. For example, NCHS was instrumental in establishing the Funding Opportunity in Survey and Statistical Research (FOSSR), a grants program that annually supports investigator-initiated basic survey research projects related to future needs of federal statistical agencies (*26*). Examples of FOSSR-funded research projects are as follows: cognitive and visual issues in Web survey designs, model-based replication variance estimators for sample surveys, and adaptive sample designs in network and spatial settings. FOSSR is jointly funded by NSF and a consortium of about a dozen federal statistical agencies, including NCHS, and is jointly administered by NSF and the Office of Management and Budget's Federal Committee on Statistical Methodology.

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Vaccine-Preventable Diseases, Immunizations, and *MMWR* — 1961–2011

Alan R. Hinman, MD[1]
Walter A. Orenstein, MD[2]
Anne Schuchat, MD[3]
[1]*Task Force for Global Health, Decatur, Georgia*
[2]*Rollins School of Public Health, Emory University, Atlanta, Georgia*
[3]*National Center for Immunization and Respiratory Diseases, Centers for Disease Control and Prevention, Atlanta, Georgia*

Corresponding author: Alan R. Hinman, MD, Task Force for Global Health, 325 Swanton Way, Decatur, GA 30030; Telephone: 404-687-5636; Fax: 800-765-7520; E-mail: ahinman@taskforce.org.

Introduction

In the 50 years since *MMWR* became a responsibility of CDC, understanding has been enhanced of diseases now prevented by vaccines, many new vaccines have been introduced, the occurrence of most of these diseases has been dramatically reduced, and some challenges not previously anticipated have appeared. This article summarizes some of these changes over three periods: 1961–1988, 1989–1999, and 2000–2010.

In 1961, children in the United States received vaccines to prevent five diseases: diphtheria, tetanus, pertussis, poliomyelitis, and smallpox. Now children receive vaccines to prevent 16 conditions: diphtheria; *Haemophilus influenza* type b, hepatitis A, hepatitis B, and human papillomavirus infections; influenza, measles, meningococcal disease, mumps, pertussis, pneumococcal disease, poliomyelitis, rotavirus infections, rubella, tetanus, and varicella (Table 1). Immunization coverage rates among preschool-aged children are high (Figure 1), and most diseases have declined to historically low levels (Table 2).

TABLE 1. Year of U.S. licensure of selected childhood vaccines

Vaccine	Year of first US licensure
Tetanus toxoid	1943
Trivalent inactivated influenza	1945
Tetanus and diphtheria toxoids	1953 for children aged >7 yrs; 1970 for children aged <7 yrs
Inactivated polio	1955
Oral polio	1963
Diphtheria–tetanus–pertussis	1970
Diphtheria–tetanus–acellular pertussis	1991
Measles–mumps–rubella	1963 (measles); 1967 (mumps); 1969 (rubella); 1971 (measles–mumps–rubella combined)
Hepatitis B	1981 (plasma derived); 1986 (recombinant)
Haemophilus influenzae type b conjugate	1987 for children aged ≥18 mos; 1990 for infants
Hepatitis A	1995
Varicella	1995
Pneumococcal conjugate	2000 (7-valent); 2010 (13-valent)
Live attenuated influenza	2003
Tetanus–diphtheria–acellular pertussis	2005
Meningococcal conjugate	2005
Rotavirus	2006
Human papillomavirus	2006

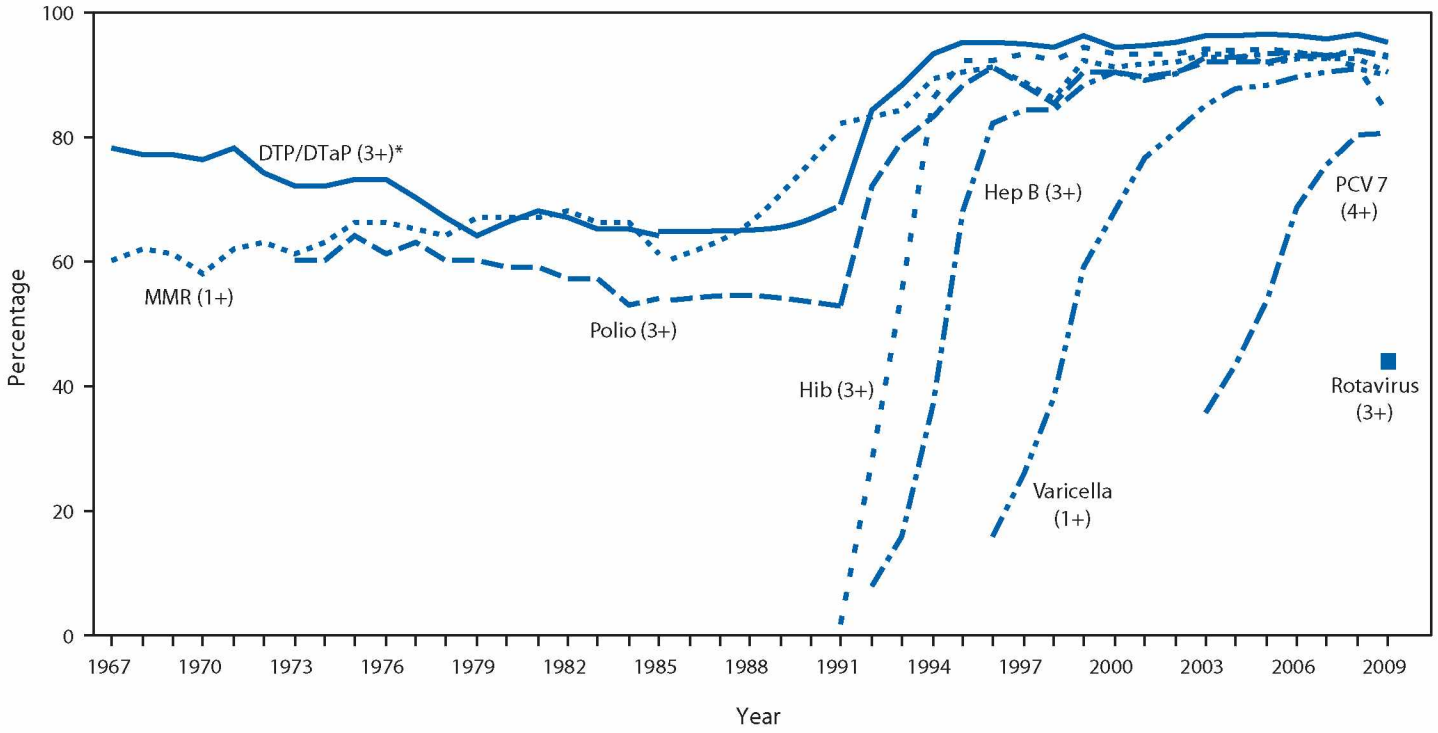
1961–1988: Establishment of a Nationwide Immunization Program

Vaccination Assistance Act

Before 1962, no formal nationwide immunization program existed. Vaccines were administered in private practices and local health departments and paid for out of pocket or provided by using state or local government funds with some support from federal Maternal and Child Health Block Grant funds. In 1962, the Vaccination Assistance Act (Section 317 of the Public Health Service Act) was passed to "achieve as quickly as possible the protection of the population, especially of all preschool children…through intensive immunization activity over a limited period of time…" The initial intention was to allow CDC to support mass, intensive vaccination campaigns. However, the Vaccination Assistance Act also established a mechanism to provide ongoing financial support to state or local health departments and direct support "in lieu of cash." The direct support included provision of vaccines and of CDC Public Health Advisors to assist in managing the programs. Section 317 has been reauthorized repeatedly since 1962 and remains one of the most important means of supporting health department immunization activities with federal funds (*1*).

At the initiation of the 317 funding program in 1963, the only vaccines routinely recommended for children were diphtheria and tetanus toxoids and pertussis vaccine (DTP), polio, and smallpox. Measles vaccine was licensed in 1963, and in 1966, a goal was set to eradicate measles from the United States (*2*). Measles incidence declined dramatically after large vaccination campaigns, but transmission was not interrupted. The licensure of rubella vaccine in 1969 led to mass campaigns to immunize children to avert an anticipated repeat of the tragic epidemic of 1964–65, which resulted in the births of approximately 20,000 infants with congenital

FIGURE. Increasing vaccine-specific coverage rates among preschool-aged children — United States, 1967–2009



Abbreviations: MMR = measles-mumps-rubella; DTP/DTaP = diphtheria and tetanus and acellular pertussis; Hib = *Haemophilus influenza* type b; Heb B = heptatitis B; PCV7 = 7-valent pneumococcal conjugate vaccine; USIS = United States Immunization Survey; NHIS = National Health Interview Survey; NIS = National Immunization Survey; NCHS = National Center for Health Statistics; NIP = National Immunization Program; NCIRD = National Center for Immunization and Respiratory Diseases.
* DTP(3+) is not a *Healthy People 2010* objective. DTaP(4) is used to assess *Healthy People 2010* objectives.
Note: Children in the USIS and NHIS were 24–35 months of age. Children in the NIS were 19–35 months of age.
Source: USIS (1967–1985), NHIS (1991–1993) CDC, NCHS, and NIS (1994–2009), CDC, NIP and NCHS; No data during 1986–1990 due to cancellation of USIS because of budget reductions.

rubella syndrome. The rubella campaigns diverted attention and funding from measles, resulting in a resurgence of measles. Federal funding for Section 317 declined during the early to mid-1970s. Immunization coverage fell, and disease increased.

In April 1977, a Childhood Immunization Initiative was announced with two goals: attainment of immunization levels of 90% in the nation's children by October 1979 and establishment of a permanent system to provide comprehensive immunization services to the 3 million children born each year in the United States. Increased funding was provided through Section 317, and a major effort was made to review vaccination records of school children and vaccinate those in need. State and local public health personnel reviewed >28 million records during a 2-year period. In addition, state and local authorities enacted and enforced school immunization requirements. By 1980, all 50 states had such laws, and since 1981, immunization levels of students entering schools have been ≥95%. Thus, the first target of the initiative was met. Achieving the second target would take considerably longer.

A major weakness of Section 317 in its early years was the assumption that state and local health departments could provide the infrastructure necessary to actually administer vaccines. Consequently, Section 317 funds were not authorized for paying salaries of persons who administered the vaccines. The result was that local health departments became increasingly unable to provide the services necessary to ensure that preschool-aged children received vaccines on time, and private sector clinicians were not filling this need, particularly in low-income communities. Additionally, no system was in place to monitor immunization coverage in preschool-aged children, so obtaining an accurate picture of population susceptibility was not possible. Inevitably, this situation led to an accumulation of susceptible children and a consequent resurgence of measles by the end of the decade.

Advisory Committee on Immunization Practices

Until 1964, recommendations about the use of vaccines in the United States were made by the American Academy of Pediatrics, the American Public Health Association, and other professional groups. The federal government's involvement

TABLE 2. Comparison of annual morbidity from vaccine-preventable diseases during the 20th century and 2009

Disease	20th Century*	2010†	% Reduction
Diphtheria	21,053	0	100
Hepatitis A	117,333	8,493§	93
Hepatitis B, acute	66,232	9,419§	86
Haemophilus influenzae type b in children aged <5 yrs.	20,000	240¶	99
Measles	530,217	63	>99
Mumps	162,344	2,612	98
Pertussis	200,752	27,538	86
Pneumococcus, invasive			
All ages	63,607	44,000††	30
<5 yrs	16,069	4,700††	72
Poliomyelitis, paralytic	16,316	0	100
Rotavirus, hospitalizations	62,500**	28,125§	55
Rubella	47,745	5	>99
Congenital rubella syndrome	152	0	100
Smallpox	29,005	0	100
Tetanus	580	26	96
Varicella	4,085,120	408,572§	90

* Estimated annual average number of cases in the prevaccine era for each disease. Source: JAMA 2007;298:2155–63.
† Source: MMWR 2011;60(32):1088–1101.
§ 2009 estimate.
¶ 23 type b and 223 unknown serotype (among children <5 years of age).
** Source: MMWR 2009;58(No. RR-2).
†† Source: http://www.cdc.gov/abcs/reports-findings/survreports/spneu09.html.

occurred through convening ad hoc expert advisory groups to address individual issues, such as the results of the field trial of Jonas Salk's inactivated polio vaccine (IPV) and the subsequent incident of paralysis related to incompletely inactivated vaccine manufactured by Cutter Laboratories. Federal ad hoc groups also provided advice about the influenza pandemic of 1957, Albert Sabin's attenuated oral polio vaccine (OPV), and soon-to-be licensed measles vaccines. The frequency and complexity of issues led CDC to propose an ongoing Advisory Committee on Immunization Practices (ACIP), which was formally established in 1964. ACIP served as a technical advisory committee to the Public Health Service. It comprised eight members, including the CDC Director, who served as Chair. Today, ACIP continues to provide formal advice to CDC and the U.S. Department of Health and Human Services; after approval, ACIP recommendations are published in *MMWR* and are available on the Internet (*3,4*).

Initially ACIP directed its recommendations to public health agencies; recommendations for private practitioners were developed by the American Academy of Pediatrics and other professional societies. To improve consistency in recommendations, liaison members from the societies have been appointed, and since 1994, all childhood vaccination recommendations have been standardized and endorsed by the Public Health Service and by professional societies. ACIP recommendations have major impact on immunization policies and practice in the United States and in other countries.

Monitoring of Adverse Events

The importance of monitoring and investigating adverse events following immunization (AEFI) is exemplified by the Cutter incident of 1955 and investigations into paralysis associated with OPV during the early 1960s. Investigations into adverse events associated with routine smallpox vaccination contributed substantially to the U.S. decision to discontinue routine smallpox vaccination in 1972, years before smallpox was eradicated globally. Reports of Guillian-Barré syndrome after receipt of swine influenza vaccine in 1976 led to nationwide investigations and contributed greatly to the development of CDC's Monitoring System for Adverse Events Following Immunization. This system was the forerunner of the current Vaccine Adverse Event Reporting System (VAERS), which was established legislatively by the National Childhood Vaccine Injury Act of 1986. VAERS is a passive surveillance system receiving reports of AEFI from providers, parents, and others. Approximately 30,000 such reports are received each year. VAERS reports describe a temporal association and cannot prove causal relationships. CDC and others have developed additional systems to permit investigation of causality. Premier among these is the Vaccine Safety Datalink, a network of eight large medical-care organizations that tracks all medical encounters (including receipt of vaccine) in approximately 9 million persons (approximately 3% of the U.S. population) (*5*).

Influenza

Surveillance of influenza disease activity and virologic characteristics are published regularly in *MMWR*, as are ACIP's recommendations for influenza vaccine use. The emergence of influenza A (H3N2) virus caused the influenza pandemic of 1968–69, and response to an A (H1N1) virus in 1976 led to the national "swine flu" vaccination program that year.

Vaccine Liability and the National Childhood Vaccine Injury Act

Manufacturers' concerns about their liability exposure to lawsuits related to AEFI (particularly paralysis after receipt of OPV) led them to transfer responsibility to the U.S. government for informing recipients of vaccine risks, as well as benefits, for vaccines administered in the public sector. The result was development of Vaccine Information Statements describing the risks and benefits and a federal requirement that each recipient (or parent) receive this notification for each dose of each vaccine. Lawsuits against manufacturers of DTP vaccine increased dramatically in the early 1980s after allegations that DTP caused permanent brain damage and sudden infant death syndrome. Some DTP manufacturers left

the market, and prices of DTP from the remaining producers rose dramatically. In 1986, the National Childhood Vaccine Injury Act was enacted, which put in place a no-fault compensation program for persons who had been injured after receipt of a vaccine that was universally recommended for children (no matter the age of the recipient). This Act also formally established VAERS, the National Vaccine Program Office, the National Vaccine Advisory Committee, and the Advisory Commission on Childhood Vaccines. Lawsuits against manufacturers declined dramatically.

Introduction of New Vaccines and Reduction of Disease during the 1960s–1980s

The incidence of polio declined dramatically after introduction of IPV in 1955 and further after introduction of OPV in 1961. The last case of paralysis from indigenously acquired polio infection in the United States occurred in 1979; the entire region of the Americas was certified free of polio in 1994. Introduction of measles vaccine in 1963 led to calls for eradication in 1966 and subsequently for elimination by October 1, 1982. Neither target was met, but measles incidence declined greatly. Introduction of rubella vaccine in 1969 led to a dramatic decline in reported rubella and congenital rubella syndrome and interrupted the cycle of recurrent epidemics at 6–9-year intervals that preceded vaccine availability.

The Certification Panel declared eradication of smallpox on December 9, 1979, and the World Health Assembly adopted the resolution declaring eradication on May 8, 1980. The last naturally occurring case occurred in 1977. Smallpox remains the only disease of humans to have been eradicated from the world thus far, but polio and dracunculiasis are nearing their eradication goals.

1989–1999: Measles Resurgence and Response

In 1989, after almost a decade (1980–1988) during which an average of approximately 3,000 measles cases were reported annually, a major resurgence began that fundamentally changed the immunization program in the United States (*6*). During 1989–1991, approximately 55,000 measles cases were reported, resulting in approximately 11,000 hospitalizations and 123 deaths. Early in the outbreak, multiple outbreaks were identified among college and high school students for whom coverage with a single dose of measles vaccine was high. During the 1980s, recognizing that measles could be transmitted among the 2%–5% of persons who did not make a primary immune response to a first dose of measles vaccine, ACIP-recommended mass revaccination campaigns as part of measles outbreak control efforts. These emergency responses were costly and logistically difficult to implement and required major diversions of resources toward outbreak control from other immunization and public health priorities. Efforts to control the multiple outbreaks among college students brought this issue to a head, and in 1989, ACIP recommended a routine second dose of measles–mumps–rubella vaccine (MMR) be administered to all children, usually at entry to school (4–6 years of age).

The major problem with measles during the resurgence was disease, not in college students, but in unimmunized preschool-aged children, often living in inner cities, and disproportionately members of racial and ethnic minority groups (*7*). Initially, the cause of the lack of vaccination was believed to be lack of access to measles vaccine. A series of studies showed that most children had access to a provider and that many had seen a health-care provider during a time when they were eligible for measles vaccination but that vaccination was not offered. Reasons for health-care providers to fail to take advantage of opportunities to vaccinate children included adherence to presumed contraindications that were not valid, reluctance to offer several vaccines simultaneously when multiple vaccines were indicated, and referral of children from private providers when parents could not pay for vaccines to public clinics where vaccines were free. The measles resurgence spurred efforts to develop comprehensive state- and community-based Immunization Action Plans that laid out the steps needed to achieve at least 90% immunization coverage of preschool-aged children for all recommended vaccines at the recommended ages during the first 2 years of life.

In 1991, the National Vaccine Advisory Committee issued recommendations laying out the blueprint for the future immunization program (*6,7*). Some of those recommendations included using federal Section 317 grant funds for actual delivery of vaccines and not simply for vaccine purchase and program administration; developing "Standards for Immunization Practice," guidelines to optimize vaccine delivery to reduce vaccine-preventable diseases; building coalitions of public and professional partners for immunization; ensuring children in other public programs (such as Women, Infants, and Children programs) were vaccinated; and enhancing assessment of immunization coverage of preschool-aged children to determine population susceptibility gaps so actions could be taken to prevent outbreaks of vaccine-preventable diseases.

Childhood Immunization Initiative and Development of the Vaccines for Children Program

In 1993, a second Childhood Immunization Initiative was undertaken with the goal of achieving, by 1996, 90% immunization coverage among preschool-aged children for vaccines recommended during the first 2 years of life. A critical part of the Childhood Immunization Initiative was to eliminate financial barriers to vaccination and ensure children could be vaccinated at their site of usual care ("medical home"), typically a private provider's office. The Vaccines for Children (VFC) program, established through the Omnibus Reconciliation Act of 1993, initiated an entitlement program for vaccines recommended by ACIP for children who were Medicaid eligible, completely uninsured, or American Indian/Alaska Native. In addition, VFC covered children whose insurance did not cover vaccinations ("underinsured")—but only if they received vaccines at Federally Qualified Health Centers (*8*). Importantly, VFC authorized ACIP to play the decisive role in which vaccines would be covered, automatically financing vaccines ACIP voted into the program. The VFC grew to cover approximately 45% of U.S. children, including about 70% of African-American and Hispanic children.

Another critical component of Childhood Immunization Initiative was the establishment of the National Immunization Survey (NIS). Starting in 1994, the NIS, through random-digit dialing surveys, obtained statistically valid immunization coverage rates for all 50 states and several urban areas, allowing tracking of progress toward meeting national goals and identification of problem areas for special interventions. The NIS documented that in 1996, ≥90% coverage was achieved for the following vaccines routinely recommended for preschool-aged children: DTP (three or more doses), polio (three or more doses), MMR (one dose), and *Haemophilus influenza* type b (Hib) (three or more doses). The Childhood Immunization Initiative goal of 70% coverage with three or more doses of hepatitis B vaccine also was met. Furthermore, racial and ethnic disparities in immunization rates, once as high as 20 percentage points for measles, had substantially narrowed (*9*).

Introduction of New Vaccines and Reduction of Disease, 1989–1999

During 1987–1999, several new vaccines were added to the childhood immunization schedule (Table 1), including Hib conjugate vaccines and hepatitis B vaccines for infants, IPV (replacing OPV), replacement of whole-cell pertussis vaccines with acellular vaccines, and varicella vaccine for all children during the second year of life.

Before the availability of Hib vaccine, an estimated 20,000 children each year developed invasive Hib disease, including 12,000 who developed meningitis. Extensive use of Hib vaccine markedly reduced these numbers and was associated with not only direct protection but with herd immunity as well (*10*).

Children who acquire chronic hepatitis B virus infection in early life have a 15%–25% lifetime risk for early death from liver failure and liver cancer. Before hepatitis B vaccine was available, >25,000 cases of acute hepatitis B virus infection were reported to CDC annually, and an estimated 30%–40% of chronic infections resulted from perinatal or early childhood infections. Initial efforts to reduce the lifetime burden of hepatitis B infection acquired in early life focused on screening high-risk (1984) and then all pregnant women (1988) for chronic hepatitis B virus infection and timely postexposure vaccination and hepatitis B immunoglobulin for their infants. Since 1991, hepatitis B vaccination has been recommended for all infants to reduce their lifetime risk for hepatitis B virus infection and to provide a safety net for infants who might otherwise not receive timely postexposure prophylaxis. In a strategy to eventually eliminate transmission of hepatitis B virus infection in the United States, vaccination has been recommended for adults at high risk for hepatitis B infection (since 1982) and all unvaccinated children and adolescents 0–18 years (since 1999). By 2000, at least 90% of infants were being vaccinated annually. In 2007, declines in reported cases of acute hepatitis B since 1998 were 92% for persons aged <20 years, 59% for persons 20-49 years, and 46% for persons ≥50 years (*11*).

During the early 1980s, allegations surfaced that whole-cell pertussis vaccines, the standard vaccines in use in the United States at the time, caused serious adverse reactions, including permanent brain damage. Although studies did not confirm these allegations, extensive efforts were made to develop acellular pertussis vaccines. These acellular vaccines were associated with substantially lower rates of fever and local reactions than were whole-cell vaccines. In 1991, acellular vaccines became available for the fourth and fifth doses of the five-dose DTP series; in 1997, acellular vaccines were recommended for the first three doses as well.

In 1995, varicella vaccine was licensed. Varicella accounted for an estimated 10,000 hospitalizations and 100 deaths each year in the United States. In 1996, ACIP recommended that all children be vaccinated against varicella with a single dose of vaccine. A universal two-dose regimen was recommended in 2006.

The last outbreak of wild-virus polio occurred in the United States in 1979. However, as a result of the exclusive use of OPV, approximately seven to eight cases of polio caused by the vaccine were reported each year (vaccine-associated paralytic

polio [VAPP]). These cases occurred in OPV recipients and in contacts of recipients. Persons with immune defects (primarily B cell) were at highest risk. With progress in the worldwide effort to eradicate polio, ACIP recommendations were updated in January 1997 to promote a sequential schedule of two doses of IPV followed by two doses of OPV to reduce the occurrence of VAPP. Because VAPP continued to occur in contacts of vaccine recipients, in June 1999, ACIP recommended that an all-IPV schedule be implemented no later than 2000. The all-IPV schedule has resulted in the near elimination of VAPP in the United States (*12*).

Diarrhea and dehydration caused by rotavirus accounted for an estimated >400,000 health-care provider visits, 55,000–70,000 hospitalizations, and 20–60 deaths annually in the United States. In 1998, RotaShield (Wyeth Laboratories, Marietta, Pennsylvania), a rotavirus vaccine derived from a strain isolated from rhesus monkeys and reassorted with three other (human) strains, was licensed. The vaccine was recommended universally for young infants. However, postlicensure surveillance documented a clustering of intussusception cases, primarily within the 3–14 days after the first dose. ACIP recommended routine vaccination stop pending further studies. A subsequent large case–control study confirmed an attributable risk for intussuception of approximately one in 10,000 first doses associated with the rhesus reassortant vaccine, and RotaShield vaccine was withdrawn (*13*). No documented cases of intussuception were reported following vaccine administered after July 16, the date of the *MMWR* publication, suggesting that the notice in *MMWR* led to marked reductions in rotavirus vaccine use.

Thimerosal

Thimerosal, an ethyl mercury–containing preservative, was added to several inactivated vaccines in multidose vials to avoid bacterial overgrowth of those vials should bacteria be introduced on repeated entry to withdraw additional doses. Before 1990, the only thimerosal-containing vaccine recommended for infants was DTP. However, recommendations for Hib and hepatitis B vaccines increased the amount of thimerosal to which infants were exposed. Overall, during the first 6 months of life, the amount of ethyl mercury in vaccines recommended for infants could exceed the levels recommended for safety by the U.S. Environmental Protection Agency for methyl mercury (a more toxic compound) but not the safety levels recommended by the Agency for Toxic Substances and Disease Registry or the Food and Drug Administration. At the time this level was recognized in 1999, no data existed to suggest any harm from the amount of ethyl mercury in vaccines. However, as a precaution, CDC recommended in 1999 that manufacturers work to decrease the amount of thimerosal in their vaccine products as soon as feasible (*14*). Use of thimerosal-containing vaccines was still recommended, until an adequate supply of vaccines not requiring a thimerosal preservative was available, to avoid the known consequences of a potential resurgence of serious vaccine-preventable diseases. Thimerosal as a preservative was generally removed by adopting single-dose packaging. Subsequent studies, including extensive research on an alleged link of thimerosal in vaccines with autism, have not supported a causal role of thimerosal in a variety of neurodevelopmental disorders, including autism (*15*).

2000–2010: New Century, New Vaccines, New Challenges

During the first decade of the 21st century, several new vaccines were introduced in the United States. Pneumococcal conjugate (PCV7 [2000]; PCV13 [2010]), meningococcal conjugate (2005), tetanus–diphtheria–acellular pertussis (Tdap, adult formulation, 2005), rotavirus (2006), human papillomavirus (2006), and zoster (2006) vaccines were recommended for routine use during this period (Table 1). Recommendations for influenza vaccines were incrementally expanded; this trend culminated in a universal influenza vaccination policy adopted in 2010. The vaccines licensed during this decade were substantially more expensive than were earlier vaccines, and consideration of the cost-effectiveness of each new vaccine became a major component of ACIP's deliberations related to routine use. During this decade, disease was substantially reduced within the vaccination-targeted age groups, as well as within unvaccinated populations. Major herd immunity benefits were associated with use of pneumococcal conjugate (*16*) and hepatitis A vaccines, in particular. Immunization coverage for the infant vaccination series (DTap–IPV–MMR–Hib–hepatitis B–varicella) neared the Healthy People 2010 target of 80% (*17*). For each birth cohort vaccinated with this series, an estimated 20 million fewer illnesses occur, 42,000 premature deaths are prevented, and $13.6 billion in direct medical costs are saved. Direct and indirect savings to society are estimated to total $69 billion (*18*).

The Changing Epidemiology of Vaccine-Preventable Disease

Although most vaccine-preventable diseases were at record low levels during this decade, several communities or institutions experienced resurgences of some vaccine-preventable

diseases, especially pertussis, mumps, and varicella. Certain factors associated with resurgent disease prompted new immunization policies (*19*). Waning immunity associated with pertussis vaccines administered during childhood prompted development of pertussis vaccine formulations that were suitable for older age groups and led to Tdap recommendations for routine adolescent and adult immunization. A single dose of varicella vaccine proved to be 85% effective, not sufficient to prevent varicella outbreaks; this finding prompted the 2006 recommendation for a routine two-dose series. Outbreaks of mumps concentrated in the midwestern United States during 2006 and the northeastern United States during 2009–2010 occurred in colleges or religious schools, despite high two-dose coverage. Indigenous measles and rubella were declared eliminated in 2000 and 2004, respectively. After elimination of endemic transmission of measles in the United States in 2000, importation of measles virus continued in low numbers annually, with limited spread. However, in 2008 more than twice the average number of annual cases occurred, associated with clustering of unimmunized children whose parents had intentionally avoided vaccinating their children (*20*). In some states, the rate of personal belief exemptions from school requirements for measles vaccine increased. Recognition of parental concerns about the number and timing of early childhood vaccines has renewed efforts to address communication needs of both providers and parents (*21*) and strengthen understanding of changing attitudes associated with immunization decisions.

Public Health Emergencies and a Pandemic

Public health emergencies during the 2000s led to some extraordinary mass vaccination efforts. The 2001 bioterrorist anthrax attack resulted in postexposure antimicrobial prophylaxis followed by voluntary vaccination of approximately 1,700 persons who had occupational exposure to envelopes contaminated with Bacillus anthracis spores. Preparedness for additional bioterrorist threats led the federal government to implement a smallpox vaccination program for civilian public health responders that reached nearly 40,000 workers) (*22*). These emergency programs were dwarfed in magnitude by the immunization program mounted in response to the first influenza pandemic in 41 years. The vaccination program against 2009 pandemic influenza A (H1N1) resulted in vaccination of an estimated 80 million U.S. residents with >90 million doses of monovalent (H1N1) vaccine (*23*). The pandemic influenza immunization program in the United States was accompanied by unprecedented levels of public and media communication and enhanced vaccine safety monitoring to optimize public acceptance. Results available thus far suggest that the monovalent pandemic (H1N1) vaccine had similar safety performance to seasonal trivalent influenza vaccines and much lower risk for Guillain Barré syndrome than that seen with the 1976 swine influenza vaccination program (*24*).

Immunization Information Systems

Immunization information systems (IIS, immunization registries) are confidential, population-based, computerized databases that record all vaccine doses administered by participating providers to persons residing within a given geopolitical area. IIS have been under development since the early 1990s and now are in place in 48 of 50 states. As of December 31, 2008, 75% of children aged <6 years were enrolled in an IIS, with at least two vaccinations recorded. An increasing proportion of IIS now cover the lifespan of the individual. The Task Force on Community Preventive Services recently reviewed the evidence base for the effectiveness of IIS and recommended IIS on the basis of strong evidence of effectiveness in increasing vaccination rates. Public health efforts are under way to improve interoperability between IIS and electronic medical records.

Global Efforts

Global efforts to reduce vaccine-preventable disease accelerated during this period, aided by catalytic investments of the Bill & Melinda Gates Foundation (www.gatesfoundation.org), as well as the formation in 2000 of the Global Alliance for Vaccines and Immunization and the associated Vaccine Fund (now GAVI Alliance) (www.gavialliance.org). Use of hepatitis B and Hib vaccines in resource-poor countries increased markedly. The World Health Organization (WHO) now recommends all infants receive hepatitis B vaccine as soon as possible after birth and all regions and associated countries develop goals for hepatitis B control. The Measles Initiative, a partnership of the American Red Cross, CDC, WHO, United Nations Children's Fund, and the United Nations Foundation, spearheaded efforts to reduce global deaths from measles by 90% from 2000 to 2010. Tremendous progress has been achieved, especially in the African region, through sustaining strong immunization services and second-dose opportunities through supplemental immunization activities (SIAs) or as a routine second dose. Maintenance of these activities will be vital to maintaining progress (*25*). Outbreaks of measles were reported in 30 countries in Africa during 2010 as a result of delays in carrying out SIAs.

During the second decade of the Global Polio Eradication Initiative (*26*), the number of countries in which endemic transmission had never been interrupted fell to four: Afghanistan, India, Nigeria, and Pakistan. However the program suffered a major setback in 2003 when Nigeria temporarily stopped polio vaccination. Cases increased substantially in Nigeria, and the virus was exported to 20 previously polio-free countries during 2003–2006, requiring major response efforts. By summer 2010, both Nigeria and India had documented substantial reductions in wild poliovirus infections compared with earlier years. However, a large outbreak of wild poliovirus type 1 in Tajikistan detected during spring 2010 emphasized the fragility of elimination efforts that have been achieved in some regions and the importance of supporting strong routine immunization efforts and sustaining heightened surveillance for poliovirus and acute flaccid paralysis. Attainment of Millennium Development Goal 4—to reduce child mortality by two thirds by 2015 from 1990—will depend in part on strengthening immunization systems and introducing pneumococcal and rotavirus vaccines to areas of high mortality in sub-Saharan Africa and Asia.

Vaccine-Preventable Diseases, Immunizations, and *MMWR*

MMWR has played a major role in chronicling key events related to vaccine-preventable diseases and immunization, carrying articles about outbreaks of vaccine-preventable diseases (even before vaccines were available for many of them), the effect of vaccines, vaccine coverage, AEFI, and the recommendations of ACIP. A review of the tables of contents of articles published in the *MMWR* weekly during 1965–2009 (tables of contents were not published before 1965) indicates >2,500 articles published—an average of approximately one article per week over the entire period (Table 3). Articles on influenza were most numerous (684), followed by measles (451), polio (249), "other" (238), and ACIP recommendations (237). Many of the episodes first reported in *MMWR* were subsequently published in peer-reviewed journals.

The Future

During the past 50 years, immunization has led to elimination or near elimination of several vaccine-preventable diseases in the United States and has substantially reduced deaths, disabilities, and illness. Maintaining success depends on sustaining

TABLE 3. *MMWR* articles in which vaccines and vaccine-preventable diseases are the sole or primary topic, 1965–2009*

Topic	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2009	Total	Grand total
Articles from ACIP	23	16	34	27	29	25	31	22	30	**237**	**237**
Diphtheria	19	20/2†	5/1†	1	0	0/1†	2/4†	2	0	**49/8†**	**57**
Hepatitis A	0	12/1†	4	4	1	3	7	3	8	**42/1†**	**43**
Hepatitis B	1	10	2	6	8	9	7	13	7/1†	**63/1†**	**64**
Hepatitis, other§	40/1†	18	10	2	4/1†	1	2	4/1†	10	**91/3†**	**94**
Hib	0	4	1/1†	0	3	4	5	2	5/1†	**24/2†**	**26**
HPV	0	0	0	0	0	0	0	0	0	**0**	**0**
Influenza	73/22†	63/21†	65/40†	86/10†	67/9†	29/4†	29/7†	48/4†	104/3†	**564/120†**	**684**
Measles	137	48/1†	48/3†	79/4†	36/3†	17/1†	10/11†	11/16†	9/17†	**395/56†**	**451**
Meningococcal disease	33/1†	10/2†	8/1†	1	1/1†	1/1†	5	3/1†	12	**74/7†**	**81**
Mumps	3	4	2	4/1†	4	0	1	0	8	**26/1†**	**27**
Pertussis	2	0	4/1†	5/1†	2	3	5	6	7	**34/2†**	**36**
Pneumococcal disease	0	0	1/3†	2	3	1	6	13	9/1†	**35/4†**	**39**
Poliomyelitis	27/3†	10/7†	12/11†	5/5†	2/6†	3/15†	3/45†	1/56†	4/34†	**67/182†**	**249**
Rotavirus	0	0	0/1†	0	0	0	4	2/1†	3/1†	**9/3†**	**12**
Rubella	4	17/2†	18	16	11	4	3	2	3/1†	**78/3†**	**81**
Smallpox	8/36†	3/36†	5/20†	7/4†	1/1†	0	0/2†	21	8	**53/99†**	**152**
Tetanus	5/1†	1	1	0	3	4/1†	4/1†	2	0	**20/3†**	**23**
Varicella	1	5	0/1†	2/1†	1	2	7	6	7	**31/2†**	**33**
Zoster	0	8	7	2	0	0	0	0	0	**17**	**17**
Other¶	1	3	7	4/1†	10	44¶/1†	68*/3†	57*/2†	33/4†	**227/11†**	**238**
Total	**377/64†**	**252/72†**	**234/83†**	**253/27†**	**186/21†**	**150/24†**	**199/73†**	**218/81†**	**267/63†**	**2,136/508†**	**2,644**
Grand total	**441**	**324**	**317**	**280**	**207**	**174**	**272**	**299**	**330**	**2,644**	

Abbreviations: ACIP = Advisory Committee on Immunization Practices; Hib = *Haemophilus influenzae* type b; HPV = human papillomavirus.
* Includes years when monthly or quarterly immunization tables were printed.
† Cases from United States or US leads/cases from other countries or reported globally.
§ Hepatitis, other indicates viral hepatitis, hepatitis not otherwise specified, non-A non-B hepatitis, or hepatitis C.
¶ Other includes vaccination coverage surveys or multidisease or combination vaccine articles.

a strong vaccine-delivery system in both public and private sectors, while ensuring adequate surveillance of disease and of vaccine coverage. Key opportunities for future progress in the United States include improved access to preventive services, such as vaccines among adults through implementation of the Patient Protection and Affordable Care Act of 2010, and performance improvements and efficiency that should result from enhanced interoperability of IIS and electronic health records. The health and economic benefits of vaccines and immunization already evident in wealthier countries are potentially achievable throughout the world through the introduction of new and underused vaccines reaching the 20% of children not yet covered through routine immunization efforts, and effectively integrating other interventions into routine immunization services. Research advances may bring new transformative interventions, such as an effective malaria vaccine, during what Bill Gates has dubbed the Decade of the Vaccine (*27*). The future could also implement a key lesson learned from the outbreak of 2009 pandemic influenza A (H1N1) by investing in innovative technologies that will permit faster production of large quantities of influenza vaccine, which could improve the effectiveness of response to the next influenza pandemic and improve the control of seasonal influenza. In future decades, the long-term benefits of vaccinating girls against human papillomavirus, both in developed countries and around the world, should be manifested by major reductions in cervical cancer and its precursors. Successful eradication of polio in the remaining reservoir countries will be a permanent gift from this generation to all future ones.

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Control of Health-Care–Associated Infections, 1961–2011

Richard E Dixon, MD
Health Net of California, Rancho Cordova, California

Corresponding author: Richard E. Dixon, MD, Regional Medical Director; Health Net of California, Inc., 11971 Foundation Place; Rancho Cordova, CA 95670; Telephone: 916-935-1941; Fax 800-258-3506; E-mail: rdixon@RLAtech.com.

Introduction

For centuries, hospitals have been known as dangerous places. In 1847, Ignaz Semmelweis presented evidence that childbed fever was spread from person to person on the unclean hands of health-care workers (*1*). Semmelweis's findings did not immediately improve sanitary conditions in hospitals, but surgeons gradually adopted aseptic and antiseptic techniques and became leading innovators of techniques to reduce patients' susceptibility to postoperative infections. Concerns about the spread of infection by air, water, and contaminated surfaces gradually changed practices in hospitals, making them safer. During the 1950s, epidemic penicillin-resistant *Staphylococcus aureus* infections, especially in hospital nurseries, captured the public's attention and highlighted the importance of techniques to prevent hospital-acquired infections, now also referred to as health-care–associated infections (HAIs; i.e., nosocomial infections) (*2*). By the mid-20th century, some surgeons, microbiologists, and infectious disease physicians had focused their studies on the epidemiology and control of HAIs (*3,4*). From the efforts of these pioneers grew the notion that hospitals had the ability—and the obligation—to prevent HAIs.

By the 1960s, hospital-based infection control efforts had been established in scattered hospitals throughout the United States. The number of hospitals with HAI control programs increased substantially during the 1970s, and HAI control programs were established in virtually every U.S. hospital by the early 1990s. The remarkable spread and adoption of programs designed to prevent and control HAIs hold valuable lessons about the ways that other public health initiatives can be designed, developed, and implemented. This report traces the strategic and tactical steps used to bring about a major public health success: the ubiquity of formal established infection control programs in virtually all U.S. hospitals and expanding into other health-care settings.

Developing the Public Health Model for Hospital Infection Control

By the late 1950s and early 1960s, a small proportion of hospitals had begun to implement programs designed to understand and control HAIs. The pioneering leaders of those efforts were located mostly in large, academic medical centers, not in public health agencies. Although state, local, and federal public health agencies were sporadically called on to provide epidemiologic or laboratory support to investigate particular problems, they did not consider hospitals as communities needing ongoing public health resources. Nor did hospitals routinely see themselves as communities needing such assistance. During the 1950s and even afterwards, many hospitals saw themselves as "the doctor's workshop" and their roles as providers of space and personnel to support practicing physicians. In most communities, a hospital was perceived as good because doctors who practiced there were perceived as good, not because the hospital's outcomes were better than its competitors'. Focused on patients and doctors as individuals, most hospitals neither tracked nor had systems in place designed to improve their overall outcomes; public health–based and population-based principles often were not important management priorities. The nosocomial staphylococcal epidemics of the 1950s began to change those attitudes.

History did not record who first understood—or when it was first recognized—that hospitals are discrete communities in which public health principles could be used to prevent and control HAIs. But by the 1960s, hospital-based clinicians and CDC epidemiologists clearly were beginning to apply a public health model to HAIs. That model was built around systematic surveillance to identify HAIs; ongoing analysis of surveillance data to recognize potential problems; application of epidemic investigation techniques to epidemic and endemic HAIs; and implementation of hospitalwide interventions to protect patients, staff, and visitors who seemed to be at particular risk.

One might assume that the public health system would have managed the public health approach to HAIs. It did not. Instead, a different approach evolved. Hospitals built and managed their own infection control programs. The historical record is murky as to why infection control programs became the responsibility of hospitals, rather than local, state, or national public health agencies. Although many exceptions certainly existed, hospitals generally did not work closely with their local health departments, and when they did interact, the health departments were sometimes seen to be regulators, not colleagues. A perception at the time was that most health departments had little interest in the hospitals' clinical activities.

Given the absence of a tradition of collaboration between community hospitals and local health departments, two of CDC's first public health research and development activities were embedded in hospitals themselves. One was a national network of hospitals that volunteered to conduct HAI surveillance by using CDC methods and to report those data to CDC each month. That voluntary surveillance system, the National Nosocomial Infection Surveillance program, has changed over the years but remains active as the National Healthcare Safety Network (NHSN; http://www.cdc.gov/nhsn/) and continues to provide information about the changing patterns of HAIs.

The second of CDC's research projects also was located in community hospitals, and it profoundly affected the evolution of infection control programs. The Comprehensive Hospital Infections Project (CHIP) was begun in 1965 (5). Eight community hospitals, which were located in different cities across the country, participated in the project. Those hospitals served as the laboratories where surveillance and control techniques were developed. CDC funded those activities, and Atlanta-based CDC staff actively collaborated in the research. Physician and nurse epidemiologists, along with CDC microbiologists, visited CHIP hospitals regularly and conducted studies to learn the epidemiology of HAIs. CHIP studies helped to define how HAIs could be identified and distinguished from community-acquired infections. Hospital staff and CDC epidemiologists explored what data were needed to improve practices and how those data should be analyzed and reported. That direct field epidemiology experience gave CDC important insights into the ways that community hospitals worked. The close interactions with the hospitals undoubtedly helped CDC develop unique recommendations that were credible to hospitals and practical for them to use.

CDC's decision to use community hospitals for some of its early research was a strategic one. Most hospital inpatients were—and still are—treated in community hospitals. Although CDC staff interacted closely and shared ideas with leading infectious disease experts in the United States and Europe, CDC's involvement with community hospitals made the resulting infection control models and techniques more likely to be appropriate for use in the kinds of institutions where most patients get hospital care.

Promoting the Public Health Model to All U.S. Hospitals

As the infection control community developed confidence in the value of infection control programs, the next task was to assist other hospitals to adopt them voluntarily. Two barriers were obvious. First, hospitals were not required to have such programs, so the value of the activities had to be promoted to hospital administrators and clinical staffs. Because they recognized such programs as advantageous to the hospital and its patients, many hospitals voluntarily adopted and paid for such programs.

The second problem posed a larger challenge. Because local and state health departments did not have the resources to place their personnel in every hospital needing an infection control program, where would the trained infection control specialists come from? Existing hospital personnel had to be recruited and trained to use entirely new public health and epidemiologic skills.

The new jobs were often filled by existing staff nurses and laboratorians who built new careers as infection control practitioners (ICPs). The ICPs usually were supervised by hospital epidemiologists—typically physicians selected from the existing medical staff, such as pathologists or infectious disease–trained physicians. These doctoral-level program directors often were hired to provide this service part time, and many volunteered to serve without pay. Both positions—ICP and hospital epidemiologist—were newly created positions, and at the time, few ICPs or hospital epidemiologists had more than cursory formal training in epidemiology or any other public health discipline.

Training for these new careers often took place informally, on the job, by networking with colleagues in other hospitals, and by taking brief training courses. Many of the pioneer infection control programs were staffed by practitioners who had either attended a week-long training course conducted at CDC or had been trained by another practitioner who had been trained at CDC. As a result, the knowledge and attitudes of the earliest infection control staff had considerable uniformity. Those pioneers soon became the leaders of their new fields and naturally became the teachers and consultants for new practitioners. The public health model became an unofficial standard of practice; it focused on active prospective surveillance, data analysis, and reporting, and it emphasized prevention programs that relied on the education of hospital staff about infection control techniques.

Although using existing hospital staff and retraining them for their new jobs provided many advantages, this practice also had unanticipated disadvantages. Few infection control pioneers brought investigative experience to their new positions. As a result, when problems were discovered by surveillance, instead of basing interventions on locally acquired epidemiological and laboratory evidence, often they were based merely on established guidelines and recommendations that seemed logically to make the most sense. The evidence base for many of those guidelines was not strong, however, because effectiveness studies of intervention programs had rarely been conducted.

Infection Control Becomes a Profession

The rapid growth and acceptance of infection control programs was undoubtedly stimulated by the new career possibilities offered by the emerging infection control field. Staff nurses, microbiologists, pathologists, and infectious disease clinicians were eager to become part of a field that provided new skills and offered new opportunities. The professionalization of infection control practice was strengthened when, in 1972, infection control practitioners formed a professional society, the Association of Practitioners in Infection Control (APIC, now the Association for Professionals in Infection Control and Epidemiology). APIC was formed to provide practitioners with continuing professional interaction, education, and growth. A certifying program based on practitioners' education, experience, and test scores followed in 1980, further establishing infection control as an attractive career.

The hospital epidemiologists followed soon afterwards in forming their own professional society, the Society of Hospital Epidemiologists of America (SHEA), now The Society for Healthcare Epidemiology of America. Its initial membership requirements allowed only physicians to join, and physician infectious disease subspecialists accounted for most of its early members. Only several years after its founding were nonphysician epidemiologists, sanitarians, microbiologists, and other doctoral-level practitioners able to join SHEA. The doctoral-level societies were also divided. Surgeons interested in hospital-acquired infections formed their own society: the Surgical Infection Society (SIS). SIS, like the other professional associations, has expanded membership to other categories of physicians, nurses, and others with an interest in surgical infections. SIS, SHEA, and APIC have not merged, although they have developed collegial working relationships and have important collaborations.

Although the development of trained professional cadres of infection control experts in every hospital seems to be an obvious benefit, it must be asked whether infection control would have been more innovative and might have advanced faster if the practitioners of the new careers had welcomed other disciplines and other kinds of expertise into the field earlier. Would that have promoted innovation? Would it have led to faster development of an evidence base for infection control? Perhaps so. Public health officials need also to consider this question as they develop and deploy new approaches to public health practice.

Transforming Infection Control from Movement to Mandate

By the late 1970s, the infection control field was well established. It had strong presences in hospitals across the country, organized work forces, a coherent model that guided the field's activities, and a rapidly expanding body of scientific publications. A decade earlier, during the late 1960s and early 1970s, however, that degree of success was not certain. During the early 1970s, the hospital infection control movement faced the same challenges as many other public health initiatives have before it: how to increase adoption by more communities and how to convert a good idea into a virtual mandate for action.

By the mid-1970s, HAIs were recognized as a major threat associated with medical care. Despite the increasing public and professional concern about HAIs, it became apparent during the mid-1970s that not all hospitals were adopting infection control programs. CDC had ready access to national professional societies, health-care trade associations, accrediting organizations, and regulatory agencies, but infection control programs, although encouraged, were not mandated. Some hospitals had no programs at all. Other hospitals had programs, but no requirement existed to ensure they were properly staffed, well structured, or effective. The absence of a requirement that hospitals have effective infection control programs to protect the public was due, in part, to the fact that the evidence for the effectiveness of the public health model for infection control programs was mostly only anecdotal. It had a compelling story; it seemed like a good thing to do; but it was not evidence based.

CDC determined that a rigorous scientific assessment of the effectiveness of infection control programs would be necessary to propel widespread adoption of hospital-based programs. That decision led to the Study on the Effectiveness of Nosocomial Infection Control (SENIC), a rigorous assessment of infection control effectiveness that compared outcomes in hospitals with and without CDC-style infection control programs (*6*). The study was designed to determine whether infection control programs using CDC-recommended practices actually reduced the risks from HAIs. To conduct the study, 338 U.S. hospitals were randomly selected and were stratified by geography, inpatient bed capacity, and teaching status. Approximately half of the study hospitals had established infection surveillance and control programs. When that study showed that hospitals with infection control programs had significantly lower rates of HAIs than did hospitals without such programs (*7*), expectations for hospital programs changed. With strong scientific evidence supporting the value of such programs, accrediting organizations such as the Joint Commission on Accreditation of Hospitals (now The Joint Commission) mandated that accredited hospitals have infection control programs similar to those

recommended by CDC and the professional organizations of hospital epidemiologists and infection control practitioners. The Joint Commission made this an accreditation requirement in 1976 (*8*).

The SENIC study converted a movement into a mandate. Although it is widely agreed that new treatment interventions for individual patients should be tested in rigorous clinical trials, such trials are much less common for large population-based interventions. The design and conduct of assessments for population-based interventions can be difficult scientifically, legally, and ethically. They also can be expensive, and often no commercial company is interested enough to sponsor such studies. As a result, SENIC-style studies are rarely conducted by public health agencies.

Beyond its revolutionary effect on infection control practices in hospitals, the SENIC study served as an example that rigorously conducted public health research can change the credibility and acceptability of public health interventions and can speed adoption of important programs. It established how, when a public health problem is important enough, a scientifically rigorous population-based assessment can be used to propel the implementation of effective programs. In the future, public health programs are likely to face ever-greater demands for proof of worth and more competition for support, and more SENIC-style studies may be needed.

Hospital Epidemiology in the New Century

CDC continues to play an important role in HAI prevention research. CDC's Division of Healthcare Quality Promotion (DHQP) has substantial expertise in HAI control, stemming in part from decades of experience in HAI epidemiologic investigations. That, along with its central role in the public health infrastructure, gives CDC a unique opportunity and responsibility to guide and support research that directly addresses the knowledge gaps most relevant to the public health.

In addition to the important research contributions that arise directly from the core activities of outbreak investigation, laboratory support, and HAI surveillance, CDC dedicates funds for innovative extramural HAI prevention research through its Prevention Epicenter Program. DHQP began the Prevention Epicenters Program in 1997 as a way to work directly with academic partners to address important scientific questions about the prevention of health-care–associated infections, antibiotic resistance, and other adverse events associated with health care. Through a collaborative funding mechanism, DHQP staff work closely with a network of academic centers to foster research on the epidemiology and prevention of HAI, with an emphasis on multicenter collaborative research projects. The program has provided a unique forum in which leaders in health-care epidemiology can collaborate with each other and with CDC to pursue innovative research endeavors that bring into alignment both academic and public health research goals and objectives and create important synergies that might not be possible for a single academic center or without the benefit of cross-fertilization of ideas between academic and public health experts.

Research conducted through the Epicenters program has produced valuable contributions to the field and to the mission of DHQP. The program has resulted in approximately 150 peer-reviewed publications that cover a broad array of topics relevant to HAI prevention, including the epidemiology of infections caused by multidrug-resistant organisms and *Clostridium difficile*; development and testing of novel prevention strategies, such as the use of chlorhexidine bathing to prevent bloodstream infections and pathogen transmission among intensive-care unit patients; and development of novel HAI surveillance strategies that are helping to shape the future of HAI surveillance through the National Healthcare Safety Network. CDC should seek to maintain an active participatory role in HAI research.

As CDC plans its research agenda, another lesson taught by the development of infection control as a public health discipline should be remembered: sometimes public health agencies need to actually *conduct* research, not just fund it. CDC's credibility obtained through its own research was an essential factor in its ability to promote infection control programs. Working in hospitals, collecting data, and conducting field studies alongside hospital workers gave CDC a unique understanding of the challenges that hospital-based infection control personnel face. As a result, CDC recommendations were more likely to be useful and appropriate than they would have been had CDC simply funded others to do its research. Learning the subtleties of what did *not* work or what was impractical to implement was perhaps more important than learning what did work, and this was learned best by the agency conducting the research itself.

The landscape of infection control and health-care epidemiology began another dramatic shift with the publication of the Institute of Medicine (IOM) report, *To Err is Human*, in 1999 (*9*). This report revealed that thousands of patients in U.S. hospitals were injured or died each year because of medical errors—many of which might have been preventable. HAIs were recognized as a leading cause of these preventable harms. This report was followed by an influential series of investigative articles on health-care–associated infections published by the *Chicago Tribune*. These reports underscored the findings of the IOM report on the major public health effects of HAIs

and criticized hospitals for failing to prevent these infections and keeping secret the scope of the problem. The IOM report and *Chicago Tribune* articles touched off an active debate about HAI prevention and spurred action by consumers and legislatures. In 2002, four states (Illinois, Florida, Missouri, and Pennsylvania) passed laws to mandate that health-care facilities report HAIs to the public. Proponents of the legislation argued that health-care facilities would finally begin to take real steps toward preventing HAIs if they had to disclose them more openly.

Public interest in HAIs reached an important tipping point in 2005–2006 with the publication of two studies about the prevention of central line–associated bloodstream infections (CLABSIs). One study was a collaboration between CDC and the Pittsburgh Regional Healthcare Initiative and the other a collaboration between researchers at Johns Hopkins University Hospital and the Michigan Hospital Association (*10,11*). Both studies brought together staff from a large number of intensive-care units who collaborated to reduce CLABSIs by implementing a relatively simple set of interventions. The results of the studies were striking and consistent. In each, CLABSIs were reduced by roughly 65%.

Increasing awareness of the scope of the HAI problem, coupled with the recognition that a substantial portion of these infections could be prevented, galvanized even more consumers and policy makers to take action. Many other state legislatures began to debate and pass laws to mandate the public reporting of HAIs. In recognition of the growing interest in so-called public reporting, CDC worked with the Healthcare Infection Control Practices Advisory Committee to develop recommendations to help guide future legislation (*12*). These laws have now become widespread. Twenty-eight states have passed legislation that requires the public reporting of one or more HAIs, and legislation is pending in others. Federal lawmakers also have taken up the HAI issue. In 2008, as part of the larger deficit-reduction act, Congress mandated that the Center for Medicare and Medicaid Services (CMS) stop giving hospitals increased payments for the care of patients with HAIs. CMS worked closely with CDC to identify HAIs that were "reasonably preventable" to support implementation of this requirement. In 2010, Congress incorporated HAI prevention into the Value Based Purchasing program of the Affordable Care Act. CMS has elected to implement the requirement by requiring national public reporting of HAIs, beginning with CLABSIs in 2011.

CDC is playing a central role in supporting legislative mandates on HAI reporting and prevention. Laws in 22 of the 28 states that require reporting of HAIs specifically stipulate that facilities use the CDC's NHSN as the platform for that reporting. Likewise, the new CMS mandate will require submission of data to NHSN. These requirements have led to a dramatic expansion in NHSN enrollment, from roughly 300 hospitals in 2006 to approximately 3,500 in 2010. Increasingly, state health departments, with support from CDC, are leading HAI prevention efforts. Their role in HAI prevention was recognized and greatly enhanced in 2009 with passage of the American Recovery and Reinvestment Act. That legislation included $50 million to support state-based HAI prevention efforts. American Recovery and Reinvestment Act funds were distributed through CDC's Epidemiology and Laboratory Capacity grant to support state efforts to build HAI infrastructure and expand surveillance and prevention efforts. CDC staff and experts are now supporting HAI prevention efforts in 49 funded states, the District of Columbia, and Puerto Rico. Specifically, CDC subject-matter experts are helping guide the expansion and validation of HAI surveillance data and the initiation and expansion of HAI prevention.

Conclusions

Efforts to prevent and control HAIs have led to profound changes in the ways that those infections are perceived and managed in the United States and abroad. Programs focused on preventing and controlling HAIs were rare in U.S. hospitals in the early 1970s; now, they are present in virtually every hospital in the nation and in many hospitals abroad.

Among the main factors that led to this success was, most importantly, CDC's decision to use a rigorous scientific study, the SENIC study, to demonstrate that infection control programs were effective. This evidence obtained from SENIC converted infection control programs from being something worth doing into programs that must be implemented to reduce illness and death. Before SENIC, the evidence for the effectiveness of infection control programs was insufficient to make these programs mandatory. With evidence from SENIC, it was virtually impossible for hospitals to avoid implementing them.

CDC's ability to work with others to design and refine infection control programs was almost certainly aided by CDC's direct field experience investigating epidemics. Perhaps even more important was CDC's experience working directly with hospitals over a long period to design and test surveillance and control techniques. That first-hand field epidemiology helped CDC to learn how hospitals function and to design infection control programs that were practical and could be implemented.

CDC and other pioneers helped to define a new field (hospital epidemiology) and new professional disciplines (infection control and hospital epidemiology). When no training courses or job descriptions existed for those essential hospital workers, CDC provided the key early training and job-development

resources used by a large proportion of infection control pioneers. Because of CDC's early dominance in defining the work of these new disciplines, CDC profoundly affected knowledge base, work activities, and extent of the practitioners' responsibilities.

Finally, hospital epidemiology was, for many years, a misleading title for a field that mainly focused on HAIs. As the patient safety movement has vividly shown, the opportunities for strong public health skills in hospitals extend far beyond mere infection control. CDC has the capacity to continue to support that effort and thereby help prevent the range of errors, omissions, and other preventable mishaps that still plague the organizations that should heal, not harm.

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AIDS: the Early Years and CDC's Response

James W. Curran, MD[1]
Harold W. Jaffe, MD[2]
[1]*Rollins School of Public Health, Emory University, Atlanta, Georgia*
[2]*Office of the Director, CDC, Atlanta, Georgia*

Corresponding author: James W. Curran, MD, Rollins School of Public Health, Emory University, 1518 Clifton Road, NE, Room 8011, Atlanta, GA 30322; Telephone: 404-727-8720; Fax 404-712-8879; E-mail: jcurran@emory.edu.

Initial Reports

The *MMWR* description of five cases of *Pneumocystis carinii* pneumonia (PCP) among homosexual men in Los Angeles was the first published report about an illness that would become known as acquired immunodeficiency syndrome (AIDS) (*1*). Appearing 4 months before the first peer-reviewed article (*2*), the timeliness of the report can be credited to the astute clinical skills and public health sensitivity of Dr. Michael Gottlieb and his colleagues at the University of California, Los Angeles, School of Medicine and Cedars-Sinai Hospital, who worked closely with Dr. Wayne Shandera, the CDC Epidemic Intelligence Service (EIS) officer assigned to the Los Angeles County Department of Health Services.

The Parasitic Diseases Division of CDC's Center for Infectious Diseases already had become concerned about other reports of unusual cases of PCP. The Division housed the Parasitic Disease Drug Service, which administered the distribution of pentamidine isethionate for PCP treatment. Because PCP was rare and pentamidine was not yet licensed in the United States, it was available only from CDC. A review of requests for pentamidine had documented that PCP in the United States was almost exclusively limited to patients with cancer or other conditions or treatments known to be associated with severe immunosuppression (*3*). Recent requests for this drug from physicians in New York and California to treat PCP in patients with no known cause of immunodeficiency had sparked the attention of Division staff.

Shortly after the first report, additional cases of other life-threatening opportunistic infections (OIs) and a malignancy, Kaposi sarcoma (KS), were reported (*4*). After learning of these first cases, CDC, under the leadership of its Director, Dr. William Foege, formed a Task Force on Kaposi's Sarcoma and Opportunistic Infections to begin surveillance and conduct epidemiologic investigations. Despite the fiscal constraints at the time, approximately 30 CDC EIS officers and staff participated in the Task Force during the summer of 1981.

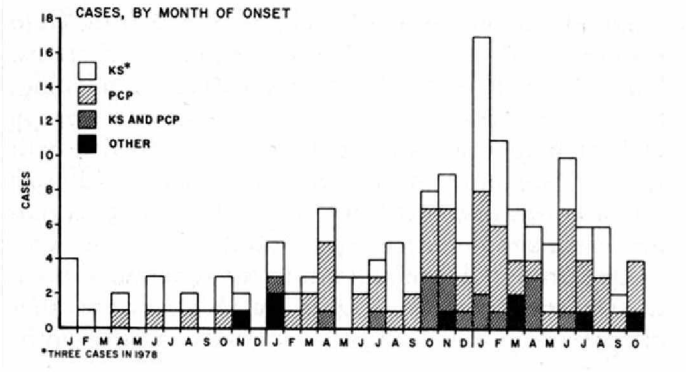
The first step for the Task Force was to establish a case definition for surveillance and investigation of the outbreak. The key underlying factor for the disease appeared to be severe suppression of the cellular immune system. The OIs initially reported were life-threatening and often fatal. Although KS was a known but infrequent cancer in the United States, the classical form of the disease was rarely life-threatening and typically occurred among elderly men. Another epidemiologic form of KS was seen among immunosuppressed renal transplant recipients.

To track KS/OI, the surveillance case definition had to emphasize specificity and accuracy of diagnosis. Thus, the original CDC case definition included 1) biopsy-proven KS among persons <60 years of age or biopsy- or culture-proven life-threatening or fatal OIs and 2) no known underlying illness (e.g., cancer or immune deficiency disease) or history of immunosuppressive therapy. This definition was soon adopted both in the United States and worldwide and was used for surveillance in countries where diagnostic capacities were available. The CDC case definition for what came to be called AIDS was modified in 1985 (*5*), 1987 (*6*), and 1993 (*7*). The World Health Organization employed a modified case definition for use in settings with limited diagnostic capacity (usually developing countries).

By the end of 1981, 159 cases of KS and OIs had been reported in the United States, with the earliest cases retrospectively identified in 1978 (*8*). By month of illness onset, cases demonstrated a clear increase over time (Figure 1). About half of the reports were for KS alone and 40% for PCP alone; 10% of patients were reported with both KS and PCP. Seventy-five percent of cases were reported from New York City or California, and all but one case were in men. Within 6 months, it was clear that a new, highly concentrated epidemic of life threatening illness was occurring in the United States. The co-occurrence of KS and OIs suggested that the epidemic was one of immunosuppression and that KS or OIs were a consequence of the immunosuppression.

Although the case definition's specificity was crucial for identifying the emerging epidemic, it lacked sensitivity. In fact, the reported KS/OI cases were described as "the tip of the iceberg" of a spectrum of illness being seen by physicians in New York City and California. These illnesses included other cancers (particularly non-Hodgkin lymphoma); thrombocytopenic purpura; and notably, persistent, unexplained generalized lymphadenopathy. Dr. Donna Mildvan and her colleagues in New York City, assisted by EIS officer, Dr. Bess Miller,

FIGURE 1. Incidence of Kaposi's Sarcoma (KS), *Pneumocystis carinii* Pneumonia (PCP), and other opportunistic infections — United States, 1979–1981



Source: Epidemiologic aspects of the current outbreak of Kaposi's sarcoma and opportunistic infections. N Engl J Med 1982;306:248–52. Reprinted with permission.

described 57 cases of unexplained lymphadenopathy among gay men (*9*). At the time, nearly one third of the reported persons with KS had a history of such lymphadenopathy. Since lymphadenopathy and other symptoms often waxed and waned, it was speculated that such findings represented a milder, if much more common, form of the syndrome.

Early in 1982, CDC conducted a national case–control study that included most living patients with KS/OIs reported in the United States. The 50 cases among gay men were compared with control gay men matched by city of residence, race, and age. The studies, led by Drs. Harold Jaffe and Martha Rogers, found that case-patients tended to be much more sexually active than controls and were more likely to have had other sexually transmitted infections (*10,11*).

In early 1982, Dr. David Auerbach, the EIS officer who had replaced Dr. Shandera in Los Angeles, was approached by a member of the local gay community about a possible sexual link between the still rare cases in southern California. In collaboration with Dr. William Darrow of the Task Force, Dr. Auerbach investigated 13 of the first 19 cases reported from Los Angeles and Orange counties and found that nine had reported sexual contact with another person reported with AIDS within 5 years before their onset of symptoms (*12*). Auerbach and Darrow then extended the epidemiologic investigation nationwide to 90 patients (approximately three quarters of reported cases among gay men alive at the time). Forty of the 90 patients in 10 cities were linked by sexual contact with another case-patient (*13*). These findings, along with the results from the case–control study, strongly suggested that the new syndrome was caused by a sexually transmissible infectious agent. Nonetheless, whether because of competing hypotheses or merely denial, many scientists and the public were skeptical of the infectious agent causation theory.

Then, in early summer 1982, an elderly man with severe hemophilia A was reported to have died from PCP. Shortly thereafter, two additional PCP cases were reported among young men with severe hemophilia from separate states. These latter cases were investigated in depth by Dr. Dale Lawrence of the Task Force, who determined that their PCP was accompanied by severe unexplained immunosuppression, and these patients had no history of homosexual contact or needle sharing (*14*). For more than a decade, persons with hemophilia in the United States had received reconstituted lyophilized clotting factor concentrates, derived from human plasma, to prevent the devastating effects of their disease. However, the concentrates were pooled from the plasma of >1,000 donors per lot and were known to transmit hepatitis viruses.

Within the next several months, AIDS cases also were reported among infants (*15–17*), female sex partners of men with, or at high risk for, AIDS (*18,19*), and an infant and adults who had received blood transfusions (*20,21*). Taken together, these cases provided strong evidence that AIDS was caused by an infectious agent that could be transmitted by blood and from mother to child, as well as through homosexual and heterosexual contact.

In the summer of 1982, life-threatening OIs and KS were also reported among 34 Haitian migrants to the United States (*22*). Most were reported to be heterosexual men with no known risk factors who had migrated from Haiti within the past 2 years. Cases of disseminated KS had been recently reported from Port-Au-Prince as well (*23*). These reports indicated an epidemiologically distinct pattern of illness that ultimately would be explained mostly by heterosexual transmission. The reporting of these cases as "Haitian entrants" was accurate and, these authors believe, necessary for public health purposes, but the stigma of "AIDS labeling" added to the already considerable burden for thousands of Haitian migrants fleeing poverty and political persecution (*24*).

Recommendations for Prevention

During the initial year after the first reports of AIDS, when the term "gay plague" was commonly used, the disease received relatively little attention from the mainstream media, the public, or politicians. By the end of 1982, however, it was clear that others were at risk for the disease, and what had been complacency turned into serious concern, even panic. Many persons caring for AIDS patients were concerned about their own safety and, in some cases, health-care workers refused to provide needed care. To provide guidance for protection of clinicians and laboratory workers managing patients with AIDS and their biologic specimens, CDC issued guidelines in

November 1982 that were based on those previously recommended to protect against hepatitis B virus infection (*25*).

In March 1983, CDC, in conjunction with the Food and Drug Administration and the National Institutes of Health (NIH), issued interagency recommendations for the prevention of AIDS on the basis of the epidemiologic data (Table) (*26*). These recommendations, which were immediately endorsed by a variety of professional and community organizations, were developed before the cause of the syndrome was discovered and 2 years before antibody testing would be available for diagnostic testing of individuals or screening of blood donations. Yet, even in retrospect, the recommendations appear to have been essentially correct. They illustrate the power of epidemiologic investigation in understanding and preventing new diseases, even in the absence of an identified cause.

The causative retrovirus was described by Drs. Francois Barre-Sinoussi and Luc Montagnier and their colleagues from the French Pasteur Institute in May 1983 (*27*). Additional proof of causality, as well as the demonstration of sustained viral growth in vitro, was reported by Dr. Robert Gallo and colleagues at the U.S. National Cancer Institute, NIH, in 1984 (*28*). In 2008, Drs. Barre-Sinoussi and Montagnier were awarded the Nobel Prize in medicine for their discovery of human immunodeficiency virus (HIV).

The availability of laboratory reagents and techniques to identify HIV led to rapid scientific advances in understanding the natural history of the infection and AIDS. CDC's Dr. Paul Feorino and colleagues first demonstrated persistent HIV infection among seropositive blood donors who had transmitted HIV many years earlier, indicating that HIV-infected persons can be asymptomatic and viremic for many years and that seropositivity is equivalent to infection and infectivity (*29*). Dr. Harold Jaffe and colleagues from the San Francisco Health Department and CDC's Hepatitis Division reported a 6-year follow-up of a cohort of gay men originally recruited in 1978 for studies of hepatitis B virus infection in San Francisco (Figure 2) (*30*). By analyzing retrospectively obtained specimens, they found that at the time the first few AIDS cases were reported from the cohort in 1981, 30% of the 7,000 men were already infected with HIV. If these data were extrapolated nationally, as many as 200,000–300,000 gay men had already been infected in the United States at the time of the 1981 case reports. Using these natural history data, Dr. Meade Morgan projected that the cumulative incidence of AIDS would reach 270,000 by 1991 (*31*). These projections provided a wake-up call to those concerned about the future economic and human costs of the epidemic in this country.

By the mid-1980s, substantial concern existed about transmission of HIV through casual contact or by arthropods. Dr. Gerald Friedland and colleagues showed no evidence of transmission among close household contacts of HIV-infected patients in New York City (*32*). In a cover story for *LIFE* magazine, physicians from Florida had postulated that the high prevalence of AIDS in Belle Glade, a small town in southern Florida, resulted from insect transmission of HIV. Dr. Kenneth Castro and his colleagues published an extensive epidemiologic investigation in that community that did not support that hypothesis (*33*).

TABLE. Recommendations for prevention of acquired immune deficiency syndrome (AIDS), March 1983

1. Sexual contact should be avoided with persons known or suspected to have AIDS. Members of high risk groups should be aware that multiple sexual partners increase the probability of developing AIDS.
2. As a temporary measure, members of groups at increased risk for AIDS should refrain from donating plasma and/or blood. This recommendation includes all individuals belonging to such groups, even though many individuals are at little risk of AIDS. Centers collecting plasma and/or blood should inform potential donors of this recommendation. The Food and Drug Administration (FDA) is preparing new recommendations for manufacturers of plasma derivatives and for establishments collecting plasma or blood. This is an interim measure to protect recipients of blood products and blood until specific laboratory tests are available.
3. Studies should be conducted to evaluate screening procedures for their effectiveness in identifying and excluding plasma and blood with a high probability of transmitting AIDS. These procedures should include specific laboratory tests as well as careful histories and physical examinations.
4. Physicians should adhere strictly to medical indications for transfusions, and autologous blood transfusions are encouraged.
5. Work should continue toward development of safer blood products for use by hemophilia patients.

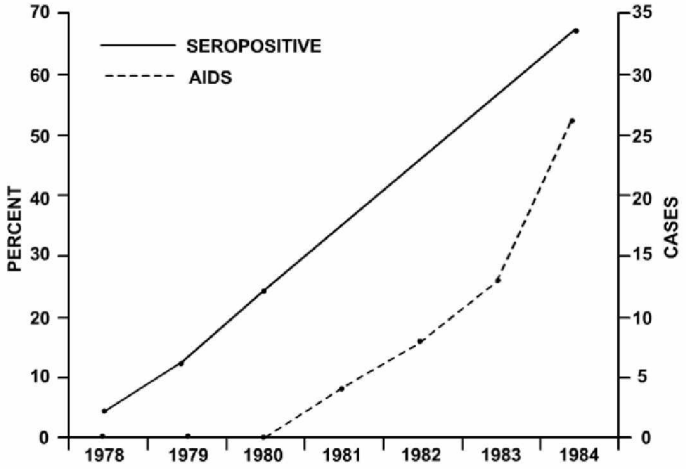
Source: CDC. Prevention of acquired immune deficiency syndrome (AIDS): report of inter-agency recommendations. MMWR 1983;32:101–3.

Drs. Steven McDougal and Linda Martin from CDC demonstrated that heat would inactivate HIV, providing a basis for production of clotting factor concentrate that would no longer transmit HIV infection (*34*). CDC laboratories also validated HIV antibody tests and provided proficiency testing materials for state public health laboratories and others. In the early HIV era, recommendations for HIV counseling and testing (*35*) and prevention of perinatal transmission (*36*) were made, and CDC provided resources and training for alternate testing and counseling sites (sites other than blood collection centers) (*37*). During the first 8 years of the epidemic, nearly 50 sets of recommendations and guidelines for AIDS were published in *MMWR*.

The Global Epidemic

By 1984, case reports described AIDS in Zaire (now the Democratic Republic of Congo), and a team of investigators including Dr. Joseph McCormick and Ms. Sheila Mitchell from CDC; Dr. Thomas Quinn from the National Institute of Allergy and Infectious Diseases, NIH; and Dr. Peter Piot

FIGURE 2. Percent of men with human T-lymphotropic virus, type III/ lymphadenopathy-associated virus antibody (seropositive) and number with acquired immunodeficiency syndrome (AIDS), by year of diagnosis, San Francisco City Clinic Cohort, 1978–1984



Source: Jaffe HW, Darrow WW, Echenberg DF, et al. The acquired immune deficiency syndrome in a context of homosexual men. A six-year follow-up study. Ann Intern Med 1985;103:210–4. Reprinted with permission.

from the Institute of Tropical Medicine in Belgium, made a joint visit to Kinshasa to verify the initial reports. Dr. Jonathan Mann was then recruited by CDC to establish a long-term project in Zaire, Project SIDA, in partnership with Dr. Bila Kapita from Mama Yemo Hospital in Kinshasa and colleagues from NIH and the Institute of Tropical Medicine. Projet SIDA would rapidly become the largest HIV/AIDS research project on the continent during the 1980s.

In 1985, CDC inaugurated and hosted in Atlanta the First International Conference on AIDS. The conference, chaired by Dr. Gary Noble of CDC, was attended by >2,000 registrants. At the conference, Dr. Mann delivered the first presentation about AIDS in Africa at a U.S. meeting and reported that the incidence of AIDS in Kinshasa was 15–30 times higher than in the United States (*38*).

Dr. Mann left Zaire to begin the Global Programme on AIDS at the World Health Organization. He was replaced as Project SIDA Director by Dr. Robert Ryder in 1986 and then by Dr. William Heyward in 1989. Dr. Kevin De Cock was the first Director of Projet Retro CI, CDC's second African research site, in Abidjan, C'ote D'Ivoire. Shortly thereafter, Dr. Bruce Weniger initiated CDC's HIV research site in Bangkok, Thailand.

Since the early days, CDC's response to the global HIV pandemic has been extensive. In the early 1980s, staff were detailed to, or volunteered from, many different parts of the agency. Initial CDC funding supported state and local health departments for surveillance and prevention activities, including HIV counseling and testing. In addition to these traditional CDC partners, hundreds of local and national community-based organizations were enlisted in the prevention efforts, and CDC provided support for school-based HIV education initiatives.

At CDC headquarters, the AIDS epidemic highlighted the need for behavioral and social scientists to participate in public health research.. Before 1981, only a handful of doctoral-trained behavioral and social scientists were on staff in Atlanta, but the numbers quickly grew. CDC's reputation and staff accomplishments also led to formation of the Global AIDS Program. Overall, many thousands of CDC staff have worked—and continue to work—with tens of thousands of colleagues throughout the world in the fight against AIDS. Well over 400 reports on HIV/AIDS have been published in *MMWR* since that first report in June 1981. The ongoing impact of CDC's scientific and programmatic contributions remains outstanding.

Lessons for the Future

In three decades, AIDS has emerged has a major global health problem. As the world faces the long struggle to combat the epidemic, several lessons from the early days emerge.

First, excellent surveillance of the initial AIDS cases was critical in responding to the epidemic. Surveillance was first needed to track the epidemic and direct etiologic investigations but later became critical in formulating early prevention and safety recommendations before HIV was discovered. Surveillance remains equally important now throughout the world to target resources and evaluate prevention efforts.

Second, the rapid identification of HIV as the causal agent of AIDS led to a much better understanding of transmission, natural history, and spectrum of illness. This understanding allowed for more targeted prevention efforts and paved the way for development of the first effective treatments.

Third, innovative science has in many ways exceeded the expectations of skeptics. These innovations include improvements in HIV diagnostics, such as rapid antibody testing and viral load assays; identification of zidovudine (AZT), the first antiretroviral (ARV) drug; use of ARVs to reduce perinatal transmission; effectiveness of prevention in many communities through counseling and testing, as well as behavior-based methods; and development of effective biomedical interventions, such as male circumcision, preexposure prophylaxis, and vaginal microbicides in addition to condom use and needle and syringe exchange. Finally, development of the three-drug ARV regimen (highly active antiroviral therapy [HAART]) has saved the lives of millions of persons with HIV infection in both the developed and developing worlds.

Fourth, as with most health problems where the etiology is well understood, prevention deserves primacy. Several million persons become newly infected with HIV each year, yet only approximately five to six million persons worldwide have been treated with HAART. The goal of universal HIV treatment cannot be met unless HIV incidence can be reduced. Furthermore, as long as the majority (or a substantial minority) of HIV-infected persons are unaware of their infection status, prevention and treatment efforts will be hampered.

Finally, committed persons have made—and will continue to make—the difference. Persons with HIV infection have played crucial roles in communities throughout the world by giving voice to their concerns and courageously advocating for HIV. Scientists in many disciplines who continue to discover breakthroughs for prevention and care provide hope for the future. Clinicians and caregivers and public health practitioners will pursue their work with an expanded science base.

The future of prevention and care for HIV means standing up to two societal foes, scarcity and discrimination, as much as the biologic challenge of the virus itself. Global resources for prevention and care for HIV remain severely short of the needs. Successful efforts for prevention must also include sustained and visible efforts to combat stigma and prevent discrimination.

This last lesson was emphasized by the late Jonathan Mann, who perished with his wife, HIV vaccine researcher, Mary Lou Clements-Mann, in a 1998 plane crash. Dr. Mann was the person most responsible for first calling world attention to AIDS and linking it to concerns about human rights. In one of his last public addresses, on the occasion of the 50th anniversary of the Universal Declaration of Human Rights, he stated, "Our responsibility is historic. For when the history of AIDS and the global response is written, our most precious contribution may well be that, at a time of plague, we did not flee, we did not hide, we did not separate ourselves" (*39*). The hope for the tens of millions affected by HIV currently and in the future will depend upon scientists, practitioners, and citizens working together.

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Fifty Years of Progress in Chronic Disease Epidemiology and Control

Patrick L. Remington MD[1]
Ross C. Brownson, PhD[2,3]
[1]*Department of Population Health Sciences, School of Medicine and Public Health, University of Wisconsin, Madison, Wisconsin.*
[2]*Prevention Research Center in St. Louis, George Warren Brown School of Social Work, Washington University in St. Louis, St. Louis, Missouri*
[3]*Department of Surgery and Alvin J. Siteman Cancer Center, Washington University School of Medicine, Washington University in St. Louis, St. Louis, Missouri*

Corresponding author: Patrick L. Remington, MD, 4263 Health Science Learning Center, 750 Highland Avenue, Madison, WI 53705; Phone: 608-263-1745; Fax: 608-262-2327; E-mail: plreming@wisc.edu.

Introduction

During the past century in the United States, advances in public health and health care have increased life expectancy by approximately 30 years and led to dramatic changes in the leading causes of death (*1*). As chronic diseases became the leading causes of illness and death in the United States by the middle of the 20th century (*2*), public health researchers began to shift their focus to identifying their complex and interrelated causes. In addition, researchers began to study ways to prevent and control chronic diseases through clinical and community-based interventions. This increasing importance and interest in chronic diseases led to the establishment of the National Center for Chronic Disease Prevention and Health Promotion at CDC in 1988 and is reflected in the publication of articles about chronic diseases in *MMWR*, with few if any articles before 1980, increasing to about 20% of articles since 1990 (Figure 1).

Considerable progress has been made during the past 50 years in understanding the causes of chronic diseases, as well as in development of the evidence for effective strategies to prevent, detect, or control chronic diseases (*3*). This report focuses on progress in four areas by:

- Describing progress in understanding the causes of chronic disease through epidemiologic research;
- Describing advances in understanding the evidence base for prevention and control, through intervention research;
- Assessing the impact of these advances on the prevalence of chronic diseases in the United States, as measured by reductions in chronic disease morbidity and mortality; and
- Discussing the lessons learned during the past 50 years in translating this research into practice in the United States.

This report provides a synopsis of progress by using key examples within the four areas rather than an exhaustive review of chronic disease epidemiology and control during the past half-century.

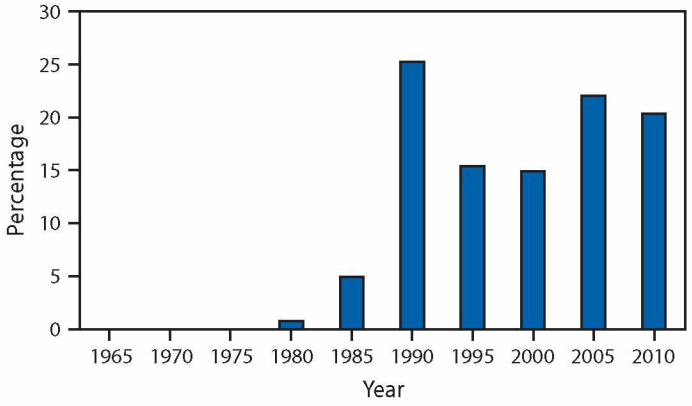
Progress in Understanding the Causes of Chronic Diseases

By the 1960s, large-scale studies such as the Framingham Heart Study, the Seven Countries Study, and the British Doctors Study, began to identify the leading causes of chronic diseases (*4*). These studies elucidated the contributions of cigarette smoking, diet, physical inactivity, and high blood pressure to the leading causes of death. Over 50 years or more, these and other studies have helped establish the behavioral causes of many of the chronic diseases affecting humans. None of these studies has established the causes of any chronic disease by itself; rather, the causes have been established on the basis of a large number of studies that used different designs and were conducted in different populations (*5*).

The discovery that smoking caused lung cancer can be viewed as the first and most important advance in chronic disease etiology. The results from the first studies of lung cancer were summarized in the first *Surgeon General's Report on Smoking and Health*, published in 1964. Establishment of the "criteria for causality" in this report was critical in the evolution of the understanding of the causes of chronic disease, given the long latency between exposures and outcomes; the multiple causes of chronic diseases; and the multiple consequences of many of the risk factors. These criteria, subsequently called the "Hill criteria," would continue to be used over time to consider the causal risk factors for other chronic diseases (*6*).

During and after the 1960s, researchers continued to study the relationship between risk factors (e.g., poor diet, lack of exercise, high blood pressure) and major chronic diseases. For example, the "diet–heart" hypothesis was tested in observational studies such as the Framingham Heart Study, a prospective cohort study of residents of Framingham, Massachusetts (*4*). At the same time, researchers shifted their focus from chronic diseases to the behavioral risk factors preceding the diseases. In 1993, these studies were summarized in the seminal publication "Actual Causes of Death in the United States" by McGinnis and Foege (*7*). These researchers used the results from decades of

FIGURE 1. Percentage of *MMWR* articles about chronic diseases, conditions, or risk factors — United States, 1965–2010



epidemiologic research to demonstrate that approximately half of all deaths could be attributed to relatively few risk factors; their work was updated later by Mokdad (*8*) (Table 1).

In 1974, the Canadian Lalonde Report (*9*) concluded that the health of a population could be considered in four broad elements: human biology, environment, lifestyle, and health-care organization. This model of the "multiple determinants of health" provides a broad conceptual framework for considering the factors that influence health in a community (*10*). This model takes a multidisciplinary approach, uniting biomedical sciences, public health, psychology, statistics and epidemiology, economics, sociology, education, and other disciplines. Social, environmental, economic, and genetic factors are seen as contributing to differences in health status and, therefore, as presenting opportunities to intervene.

Other research during this time focused on the role of social and economic factors that increased risk for chronic disease. One of the most important investigators in this field is Sir Michael Marmot, whose studies of British civil servants clearly illustrate these concepts (*11*). His and others' research have since demonstrated that health behaviors alone do not explain the risk related to occupation, income, education, and other social determinants of health (*12*). A new academic field of social epidemiology developed during this same period and became best known for identifying the social gradient in health, in which health outcome effects exist not only at the extremes of high and low levels of education and income but also at most gradations in between (*13,14*).

Research has increasingly demonstrated the contributions to health by factors beyond the physical environment, medical care, and health behaviors. These include socioeconomic position, race/ethnicity, social networks and support, work conditions, economic inequality, and social capital (*15*). These contributors were summarized in the Institute of Medicine's

TABLE 1. Actual causes of death — United States, 2000

Cause	No.	(%*)
Tobacco	435,000	(18.1)
Poor diet and physical inactivity	400,000	(16.6)
Alcohol consumption	85,000	(3.5)
Microbial agents	75,000	(3.1)
Toxic agents	55,000	(2.3)
Motor vehicles	43,000	(1.8)
Firearms	29,000	(1.2)
Sexual behavior	20,000	(0.8)
Illicit drug use	17,000	(0.7)
Total	**1,158,000**	**(48.2)**

Source: Reference *8*. Mokdad AH, Marks JS, Stroup DE, Gerberding JL. Actual cases of death in the United States, 2000. JAMA 2004;291:1238–45.
* Percentages of all deaths.

Future of the Public's Health in the 21st Century, which stated that "the greatest advances in understanding the factors that shape population health during the last 2 decades…has been the identification of social and behavioral conditions that influence morbidity, mortality, and functioning" (*16*).

Progress in Developing Evidence-Based Chronic Disease Prevention and Control Programs and Policies

As information about the causes of chronic diseases accumulated during the 1960s and 1970s, research began to focus on intervention studies. Systematic reviews have been conducted to determine which interventions are effective in preventing or controlling chronic diseases (*17*). Information about hundreds of evidence-based interventions is now available from a variety of sources, including the *Guide to Clinical Preventive Services* (*18*), *The Guide to Community Preventive Services* (*19*), *MMWR Recommendations and Reports*, The National Guideline Clearinghouse (*20*), and the Cochrane Reviews. More recently, the emphasis has shifted from what constitutes acceptable intervention evidence to what processes in public health settings will enable more widespread use of evidence-based practices. Several leading discoveries that have reduced, or have the potential to reduce, the impact of chronic diseases are described below.

Clinical Preventive Services

Research demonstrated that certain clinical preventive services, including screening, counseling, and preventive medications, are effective in preventing or controlling the leading chronic diseases. During the past 50 years, for example, research has demonstrated effective ways to counsel smokers to quit; screen for breast, colon, and cervical cancer; and detect and

treat high blood pressure and high blood cholesterol. The evolution of this clinical research led to establishment of the US Preventive Services Task Force in 1984 to rigorously and impartially assess scientific evidence for the effectiveness of these and other clinical interventions. Its recommendations are considered the standard for clinical preventive services. The premier publication of the Task Force, *The Guide to Clinical Preventive Services*, provides information about preventive services that should be incorporated routinely into primary medical care, and for which populations (*18*).

Media and Policy Advocacy

Media messaging and policy advocacy can be important methods for preventing chronic diseases. For example, research has demonstrated that media and policy advocacy are effective low-cost strategies for reducing smoking rates in the population. Specifically, comprehensive programs that focus on policy changes (e.g., advertising restrictions, policies regarding clean indoor air) can effectively reduce smoking rates in populations (*21*), and these policy changes can be supported by media advocacy (*22*). Changes in the policy environment can increase demand for effective clinical interventions (e.g., physician advice to patients for smoking cessation, access to cessation services) and smoking prevention programs in organizational settings (e.g., curricula in schools that focus on effective prevention strategies).

Environmental Interventions

Research has demonstrated that environmental interventions might be effective in promoting physical activity and healthy eating (*23,24*). The built environment—the physical form of communities—includes land-use patterns (how land is used), large- and small-scale built and natural features (e.g., architectural details, quality of landscaping, access to grocery stores), and the transportation system (facilities and services that link one location to another). Together, these elements shape access to opportunities for physical activity and healthy eating.

Progress in Reducing the Impact of Chronic Diseases

Public health surveillance can be used to assess the effectiveness of the interventions described above on reducing the health burden from chronic diseases. Trends in selected chronic disease death rates and related risk factors are described below.

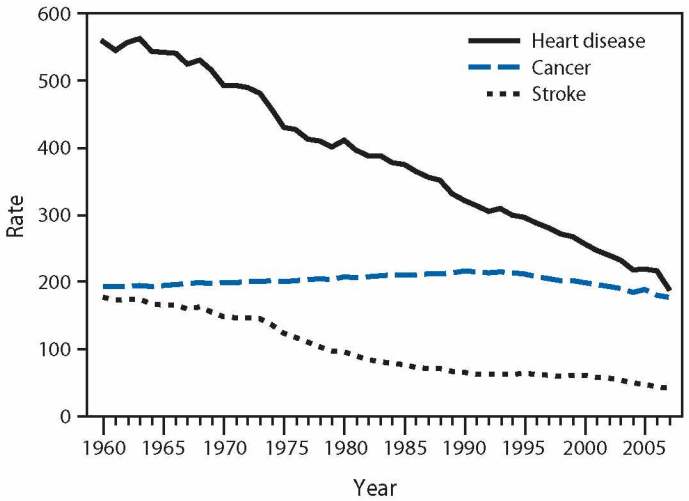
Trends in the Leading Causes of Death

Since 1960, death rates for chronic diseases have changed dramatically, especially reductions in deaths caused by heart disease and stroke (Figure 2). Heart disease death rates have declined by almost two thirds during the past 50 years, and stroke rates have declined by more than three quarters. If the 1960 death rates for heart disease and stroke had persisted, almost 1.5 million more deaths from these causes would occur each year today. These major declines have resulted largely from declines in smoking and improvements in diet, detection and treatment of high blood pressure and high blood cholesterol, and medical care and treatment (*25*).

Overall death rates for cancer have changed relatively little during the past 5 decades, declining only 8%. This translates to 49,000 fewer deaths each year today than during the 1960s (*26*). These trends vary by patient sex and type of cancer. For example, death rates for stomach, colon, uterine, breast, and prostate cancers have declined during the past few decades (*27*). However, this progress has been counterbalanced by a dramatic increase in the rate of lung cancer deaths during the past 50 years. Lung cancer became the leading cause of cancer death among men in the 1950s and among women in the 1990s. Although lung cancer rates now have started to decline, they remain substantially higher today than in the 1960s (Figures 3 and 4).

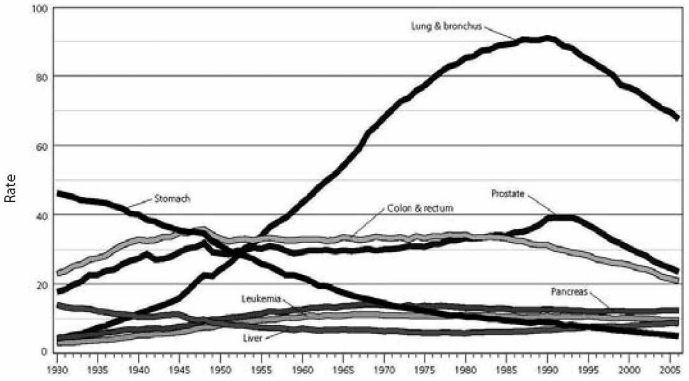
Death rates for several other chronic diseases (e.g., diabetes, chronic lung disease, chronic kidney disease) have changed little or even increased during the past 50 years. Although

FIGURE 2. Trends in age-adjusted death rates for the leadings chronic diseases — United States, 1960–2007



Source: National Center for Health Statistics. Health, United States, 2010. Hyattsville, MD: US Department of Health and Human Services, CDC, National Center for Health Statistics; 2011. Available at www.cdc.gov/nchs/data/hus/hus10.pdf.

FIGURE 3. Trends in age-adjusted cancer death rates* for males — United States, 1930–2006†

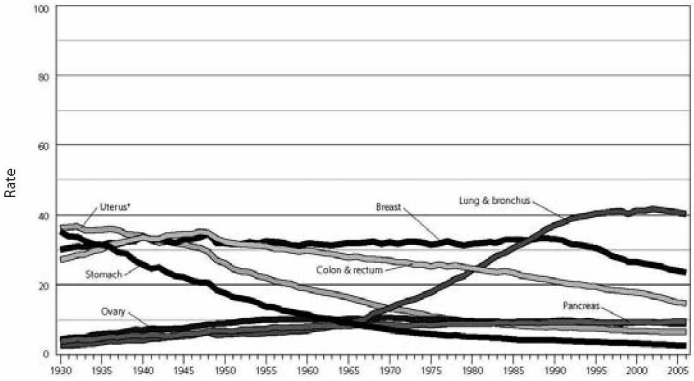


Source: US Mortality Data, 1960 to 2006, US Mortality Volumes, 1930 to 1959, National Center for Health Statistics, Centers for Disease Control and Prevention, 2009.

* Per 100,000, age adjusted to the US standard population.

† Due to changes in International Classification of Diseases coding, numerator information has changed over time. Rates for cancer of the liver, lung and bronchus, and colon and rectum are affected by these coding changes.

FIGURE 4. Trends in age-adjusted cancer death rates* for females — United States, 1930–2006†



Source: US Mortality Data, 1960 to 2006, US Mortality Volumes, 1930 to 1959, National Center for Health Statistics, Centers for Disease Control and Prevention, 2009.

* Per 100,000, age adjusted to the US standard population. Rates are uterine cervix and uterine corpus combined.

† Due to changes in International Classification of Diseases coding, numerator information has changed over time. Rates for cancer of the lung and bronchus, colon and rectum, and ovary are affected.

trends in diabetes-related deaths are difficult to assess because diabetes often is listed as a contributing cause of death, the prevalence rates of diagnosed and undiagnosed diabetes have increased steadily since the first National Health and Nutrition Examination Survey during 1960–1962 (*28*). This increase has been seen in all age groups, both sexes, and all racial/ethnic groups and across the United States. The substantial increase in obesity since the 1980s and the increased survival rates among persons with the disease have contributed to the increase in diabetes.

Death rates for chronic lower respiratory diseases, such as bronchitis and emphysema, have increased by approximately 50% during the past 30 years, from 12.5 deaths per 100,000 persons in 1980 to 42.2 per 100,000 in 2009. The increased death rate during 1960--2007 has been responsible for an excess of about 42,000 deaths each year (Table 2). Death rates have continued to increase during the past 20 years in both sexes and all racial/ethnic groups (*29*).

Trends in Risk Factors for Chronic Diseases

One of the most important successes since 1960 has been the slow but substantial reduction in smoking rates in the general population (Figure 5). The annual per capita consumption of cigarettes peaked in 1963, and except for an increase during 1971–1973, consumption has steadily declined since then. Smoking rates in the general population declined from about four of every 10 adults during the early 1960s (51.2% for men and 33.7% for women) to about two of every 10 adults today (22.0% for men and 17.5% for women) with greater declines for men than women (Figure 4) (*30*). Rates for teens remained relatively stable from 1975 to the mid-1990s but have declined steadily during the past decade (*30,31*).

In contrast, the rates of obesity for adults and children have more than doubled since the 1960s (Figure 5) (*30,32*). Prevalence rates of obesity (body mass index >30) among adults increased from <15% during the 1960s to >35% today, with most of that increase occurring since the 1980s (*30*). Although the magnitude of increase varies, the increase is observed in all age groups, both sexes, all racial/ethnic groups, and all states (*30,32*).

The causes of this obesity epidemic are complex. Since the National Health and Nutrition Examination Survey was first administered in 1971, many changes have occurred in food consumption. The quantity of food and beverages consumed, the fraction of meals eaten outside the home, portion sizes, and energy density have increased substantially (*33*). Although diets have decreased in saturated fats and cholesterol, including less red meat and more chicken, total calories consumed might have increased. In addition, evidence suggests that rates of physical activity have decreased over time (*34*). As expected, rates of diabetes and other obesity-related chronic diseases have increased during this time.

The rates of alcohol use, as measured by apparent per capita alcohol sales (gallons of ethanol) increased during the past 50 years, from 2.1 gallons per person aged >15 years in 1960 to 2.3 in 2007, after peaking at 2.8 in 1981 (*35*). However, long-term trends in the prevalence of alcohol abuse and dependence in the United States are difficult to assess. Population-based studies conducted during 1991–2002 showed that the prevalence

TABLE 2. Trends in the leading causes of chronic disease–related deaths — United States, 1960 and 2009

Disease†	Rate,* by year		Trends, 2009 vs. 1960		
	1960	2009	% Change	Rate difference*	No. lives saved (lost)§
Heart disease	559	180	–68%	–379	1,137,000
Cancer	194	174	–10%	–20	60,000
Stroke	178	38.9	–78%	–139	417,300
Diabetes	22.5	20.9	–7%	–1.6	4,800
Liver disease	13.3	9.2	–31%	–4.1	12,300
Pneumonia & influenza	53.7	16.2	–70%	–38	112,500
Accidents	62.3	37	–41%	–25	75,900
Suicide	12.5	11.7	–6%	–0.8	2,400
Homicide	5.0	5.5	+10%	+0.5	(1,500)
Total					**820,700**

Sources: Health, United States, 2010: with special feature on death and dying. Hyattsville, MD: US Department of Health and Human Services, CDC, National Center for Health Statistics; 2011. Available at www.cdc.gov/nchs/data/hus/hus10.pdf; and Kochanek KD, Xu JQ, Murphy SL, et al. Deaths: preliminary data for 2009. National Vital Statistics Reports 2011;59(4). Available at http://www.cdc.gov/nchs/data/nvsr/nvsr59/nvsr59_04.pdf.

* Per 100,000 population (age adjusted to the 2000 US population).

† For chronic obstructive pulmonary disease, comparison is 1980 vs. 2009, as follows: 1980 rate—28.3; 2009 rate—42.2; % change, 2009 vs. 1980—+49%; rate difference—+14; no. lives saved: 41,700.

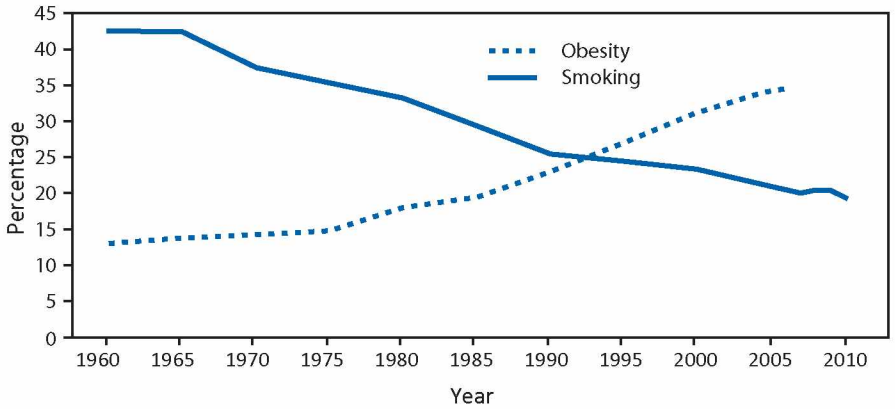
§ Estimated by multiplying the rate difference by the 2010 US population (300 million persons) rounded to the nearest 1,000.

of alcohol dependence decreased significantly (from 4.4% to 3.8%), whereas the prevalence of alcohol abuse increased significantly (from 3.0% to 4.6%) (*36*). This increase occurred among both sexes and was especially marked among young black, Hispanic, and Asian women.

Looking Back: Lessons Learned during the Past 50 Years of Chronic Disease Epidemiology and Control

Considerable progress has been made during the past 50 years in understanding the causes of chronic diseases. The successes and failures of efforts to translate this research into practice have taught some important lessons.

FIGURE 5. Trends in the prevalence of smoking and obesity — United States, 1960–2010



Source: Obesity data: National Center for Health Statistics. Health, United States, 2010. Hyattsville, MD: US Department of Health and Human Services, CDC, National Center for Health Statistics; 2011. Available at www.cdc.gov/nchs/data/hus/hus10.pdf. Smoking data: CDC. Current cigarette smoking among adults aged ≥18 years—United States, 2005–2010. MMWR 2011;60:1207–1212..

National Outreach and Education Programs

Despite advances in chronic disease epidemiology and control, a long latency period exists between scientific understanding of a viable chronic disease control method and its widespread application on a population basis. One of the first nationwide programs that successfully accelerated translation of evidenced-based interventions into practice was the National High Blood Pressure Education Program. It was established by the U.S. Congress in 1972 to promote nationwide detection, treatment, and control of hypertension through education programs and referrals. The program used a consensus-building approach to develop strategies to address hypertension through a broad-based partnership among federal agencies, national voluntary organizations, state health departments, and community-based programs.

Similar programs were used to accelerate dissemination of cholesterol screening and treatment and, more recently, a large-scale program to promote early detection of breast and cervical cancers. This CDC-supported initiative is the National Breast and Cervical Cancer Early Detection Program, which provides screening for breast and cervical cancers to low-income, uninsured, and underserved women in all 50 states, the District of Columbia, five U.S. territories, and 12 American Indian/Alaska Native tribes or tribal organizations (*37*).

Prevention and Control Interventions

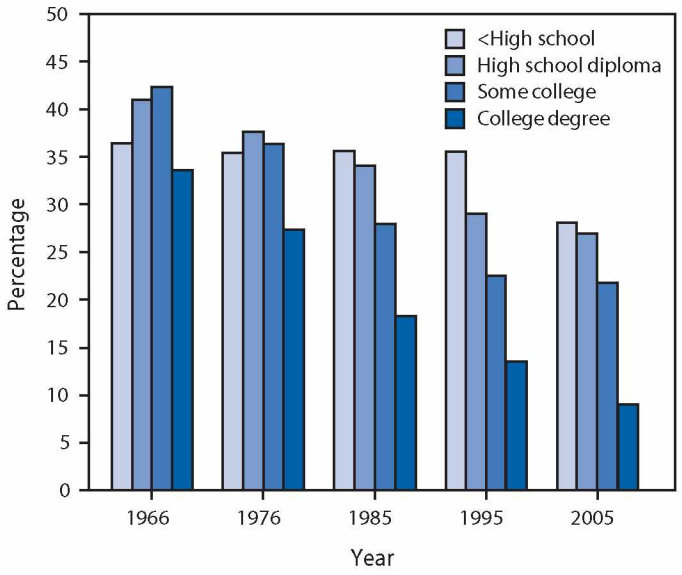
Successful chronic disease prevention and control interventions generally have used comprehensive approaches that have focused on environmental and policy changes. Success in reducing health risk behaviors in the population has resulted largely from comprehensive integration of numerous environmental and policy approaches that have complemented individual behavior and lifestyle modification strategies (*38*). For example, progress in reducing smoking rates has been greatest when state-based programs have used a comprehensive strategy including such interventions as tax increases, policies regarding clean indoor air, youth access limitations, media advocacy, and counteradvertising (*39*). A comprehensive strategy can benefit all persons exposed to the environment, in contrast to a strategy that focuses on changing the behavior of one person at a time. In nearly all cases, these interventions have required new skills and nontraditional partnerships with individuals and organizations not working directly in public health. For example, to address the major physical barriers to an active lifestyle in U.S. cities, urban planners, transportation experts, and persons working in parks and recreation are essential to developing an environment and political will that can promote physical activity.

Unintended Consequences of Interventions

One unintended consequence of many public health interventions to prevent or control chronic diseases is the development of health disparities among poor and less educated persons and minorities. Despite major progress in reducing chronic diseases and their risk factors during the past 50 years, health disparities have persisted and, in some cases, have arisen where none existed before. The most obvious example involves the trends in smoking since 1965. At that time, smoking rates were unrelated to the level of education, but today level of education is a major predictor for smoking (Figure 6). These differences in smoking rates will lead to subsequent disparities in smoking-related chronic diseases (*40*).

Disparities tend to develop as an unintended consequence when programs or policies are most effective for persons with higher levels of education (e.g., information campaigns), higher incomes (e.g., promoting healthier but more expensive foods); or health insurance (e.g., promoting the use of clinical preventive services, such as colonoscopy). Relatively few programs have been developed to specifically reduce health disparities by focusing on populations in greatest need.

FIGURE 6. Trends in the prevalence of smoking, by education level — United States, 1966–2005



Sources: CDC. Reducing the health consequences of smoking: 25 years of progress—a report of the Surgeon general. Rockville, MD: US Department of Health and Human Services, Public Health Service, 1989; 269, and National Center for Health Statistics. Table 59. Age-adjusted prevalence of current cigarette smoking among adults 25 years of age and over, by sex, race, and education level: United States, selected years 1974–2009. In: health, United States, 2010. Hyattsville, MD: US Department of Health and Human Services, CDC; 2010; 231.

Surveillance Data

Surveillance data can be effective in mobilizing action toward community health. Public health surveillance has evolved during the past 50 years, broadening its scope from infectious diseases to chronic diseases. For example, CDC's National Program of Cancer Registries now supports central cancer registries in 45 states, the District of Columbia, Puerto Rico, and the U.S. Pacific Island jurisdictions, representing 96% of the U.S. population. Together with the National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER) Program, cancer incidence data are available now for the entire U.S. population.

During the 1980s, CDC established surveillance systems to monitor trends in risk factors for chronic diseases among adults (Behavioral Risk Factor Surveillance System [BRFSS]) and children (Youth Risk Behavior Surveillance System [YRBSS]). These state-based systems for the first time provided information for state and local health departments (e.g., the Selected Metropolitan/Micropolitan Area Risk Trends BRFSS (SMART BRFSS) for program planning and evaluation. The colored maps showing the increasing rates of obesity in every state during the past several decades have been seen by countless professionals, students, and members of the public.

The Future

The past 50 years have seen major progress in understanding of the causes of the leading chronic diseases, from the role of behaviors to the importance of social, economic, and environmental factors. This better understanding has been used to develop effective interventions in both clinical and community settings. However, despite some success, much more must be done to reduce further the effects of chronic diseases during the next 50 years.

First, epidemiologic research must continue to elucidate the causes of several important chronic diseases, such as Alzheimer disease and other dementias; mental disorders, such as depression; and substance abuse. Large, prospective population-based studies are needed to determine the influence of genetic, behavioral, social, economic, and environmental exposures on health outcomes over the lifespan. In addition, more research is needed to identify the specific social, cultural, or environmental factors that influence health behaviors, such as exercise and healthy diets.

Second, continued development of evidence for chronic disease prevention and control programs and policies is needed and must move beyond the "what" to the "how." Systematic reviews such as the *Community Guide* may illustrate the potentially effective interventions. Equally important for practitioners is better information about the factors that need to be considered when a research-tested program or policy is implemented in a different setting or in a different population. If the adaptation changes the original intervention to such an extent that the original efficacy data might no longer apply, then the program should be viewed essentially as a new intervention.

Third, continued support is needed for broad-based programs that accelerate translation of research into practice. Most importantly, perhaps, changes are needed in means of funding health care, shifting the incentives from paying for more care to paying for good health. With such a system, demand for evidence-based programs and policies would increase and further accelerate their adoption. Current efforts, such as CDC's state-based chronic disease prevention and control programs, address most major chronic diseases and risk factors, but in many cases they do not cover all states and in many other cases are not comprehensive enough to reach populations at highest risk for disease. Increasing support might be challenging, given the current economic climate in the United States and competing demands for government revenue.

Fourth, trends in chronic diseases and their risk factors should continue to be monitored, and surveillance should be expanded to focus on certain policy issues. Public health surveillance is a cornerstone of public health (*41*). The United States now has excellent epidemiologic data for estimating the person, place, and time dimensions for chronic diseases. Better information about a broad array of environmental and policy factors is needed to supplement these data. For example, future environmental and policy surveillance systems may include information about perceived access to healthy foods or places for physical activity. When implemented properly, such novel surveillance systems can be an enormous asset for policy development and evaluation.

Finally, public health needs to ensure that all groups in the population benefit from progress in the whole population. The federal Healthy People 2020 process, as well as state and local counterparts, can play critical roles by focusing on improving health outcomes among all groups in society. Most importantly, these efforts must have the means to regularly assess progress and engage stakeholders who share accountability for improving the public's health. The full potential of science will be achieved only when all available scientific knowledge is applied to practice and for all societal groups.

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Injury Prevention, Violence Prevention, and Trauma Care: Building the Scientific Base

David A. Sleet, PhD[1]
Linda L. Dahlberg, PhD[1]
Sridhar V. Basavaraju, MD[2]
James A. Mercy, PhD[1]
Lisa C. McGuire, PhD[1]
Arlene Greenspan, DrPH[1]
[1]*National Center for Injury Prevention and Control, CDC, Atlanta, Georgia*
[2]*Center for Global Health, CDC, Atlanta, Georgia*

Corresponding author: David A. Sleet, PhD, Division of Unintentional Injury Prevention, National Center for Injury Prevention and Control, CDC, 4770 Buford Highway, MS F62, Atlanta, GA 30341; Telephone: 770-488-4699; Fax: 770-488-1317; E-mail: dds6@cdc.gov.

Introduction

Injuries and violence are widespread in society. Unintentional injuries and injuries caused by acts of violence are among the top 10 killers of U.S. residents of all ages. Injuries are the leading cause of death of persons aged 1–44 years and a leading cause of disability among persons of all ages, regardless of sex, race/ethnicity, or socioeconomic status. Nearly 180,000 persons die each year from unintentional injuries or from acts of violence, and one in 10 sustains a nonfatal injury serious enough to require treatment in a hospital emergency department (*1*). In addition, injuries and violence have a major effect on the well-being of Americans by contributing to premature death, disability, poor mental and physical health, chronic disease, and other health conditions, as well as high medical costs and lost productivity.

The science of injury prevention and control encompasses activities from primary prevention through treatment and rehabilitation. Since 1961, when *MMWR* was first published by CDC, progress has been made in developing the science of injury prevention and control, creating surveillance systems to capture injury mechanisms and intent, and establishing a scientific framework to address injury prevention and treatment.

Perspectives on Unintentional Injuries and Public Health

Many consider the first 50 years of the 20th century as the prescientific era of injury control because of the prevalent perception at the time that injuries resulted from inevitable, random, or unavoidable events, termed accidents. Many public health officials believed that injury prevention was outside the realm of scientific inquiry because it could not be predicted or controlled. Epidemiologic data were difficult to obtain, and patterns in injuries had not been systematically reviewed.

History of Injury before 1961

The National Safety Council was founded in 1913 as a clearinghouse for safety data and information, which previously had been lacking. Injury or accident prevention progressed largely by trial and error. In 1923, Julian Harvey introduced the three Es (education, engineering, and enforcement) to control the causes of accidents (*2*). However, an epidemiologic framework for the ways these approaches work to reduce injuries was not available for another 40 years.

The scientific approach to injuries developed during 1940–1950 laid the groundwork for a public health understanding and response (*3*). Hugh De Haven studied cases in which persons fell 50–150 feet without sustaining serious injury. He observed that the type of force and its distribution across the body contributed to injury (*4*). This discovery later allowed for engineering designs that prevented or modified energy exchange, such as seat belts, dashboard padding, automobile crush zones, and bicycle helmets.

In 1949, John E. Gordon suggested that injuries, like classic diseases, were characterized by epidemic episodes, seasonal variation, long-term trends, and demographic distribution (*5*). He further explained how injury, like disease, was the product of at least three sources: the host, the agent, and the environment.

Ten years later, in 1959, James Gibson, an experimental psychologist who applied traditional epidemiologic methods to the study of injuries, concluded that injuries to a living organism can be produced only by some form of energy exchange (*6*). This energy (the agent of injury) may be kinetic, chemical, thermal, radiatory, or electrical and, when released, can cause tissue damage or functional impairment. In an automobile crash, for example, the agent of injury is kinetic energy released on the host in amounts beyond human tolerance. This discovery helped clarify the energy transfer theory of injury causation as the missing component in understanding the epidemiology of traffic injuries (Figure 1). The next step would be to design interventions to break the causal chain.

Key Developments in Unintentional Injury Prevention since 1961

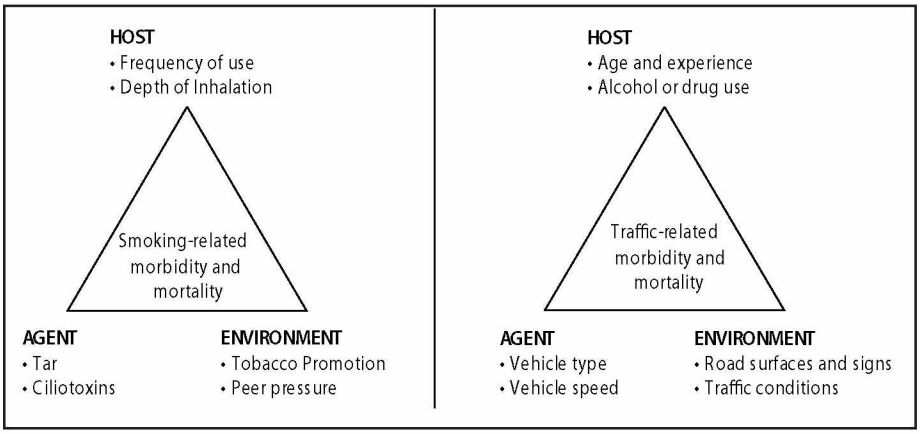
The 1960s brought new attention to injury prevention research and new scientific approaches. One of the most noteworthy advances came in the work of William Haddon, Jr., an engineer, public health physician, and director of the New York State Department of Health, who is often considered the father of modern injury epidemiology. Haddon's suggestion (*7*) that injury prevention depended on controlling the agent—energy—led him to develop strategies later applied to preventing motor vehicle–related injuries (*8*). In 1966, Haddon became the first Administrator of the U.S. government's National Highway Safety Bureau (renamed the National Highway Traffic Safety Administration [NHTSA] in 1970).

Haddon Matrix

Haddon developed a two-dimensional phase-factor matrix (The Haddon Matrix) to help conceptualize an injury event (*9*). The first dimension comprised the three factors influencing injury: host, agent (or vector), and environment; the second dimension was injury phase divided into preevent, event, and postevent. The Haddon Matrix can be applied readily to a motor vehicle crash (Table).

This framework for analysis makes possible identification of factors related to the host, agent, and environment within the three phases before, during, and after the crash that might be explanatory and contribute to injury prevention strategies. A guiding principle of injury control that emerged from Haddon's work was that effective injury control relied on a combination of intervention strategies. Estimates suggest that federal motor vehicle safety standards resulting from application of Haddon's energy exchange management approach saved an estimated 328,551 lives during 1960–2002 (*10*).

FIGURE 1. Parallels in the epidemiologic triad related to smoking harm and traffic injury



Source: Sleet DA, Gielen A. Injury prevention. In: Health promotion handbook. Arnold J, Gorin SS, eds. St. Louis, MO: Mosby; 1998.

Federal Leadership

Adding to the impetus for a more disciplined approach to injury control was the 1966 National Research Council's landmark report, *Accidental Death and Disability: The Neglected Disease of Modern Society* (*11*). This report documented how little scientific progress had been made in understanding injury causation or in applying what was already known to reduce injuries and improve trauma outcomes.

Early federal programs in the 1960s and 1970s were centered in the Division of Accident Prevention within the U.S. Public Health Service. At the same time, traffic safety and consumer safety were being addressed by NHTSA and the Consumer Product Safety Commission, respectively. The Highway Safety Act of 1966 and the Consumer Product Safety Act of 1972 ushered in new regulatory authority and launched an era of engineering and product regulation as bedrocks of modern injury control (*12*).

CDC

In the early 1970s, CDC began to investigate injuries, particularly in the home and recreational environment. However, not until the Institute of Medicine's landmark publication, *Injury in America* (*13*), did CDC's role in injury prevention become firmly established. That report recommended the establishment of a Center for Injury Control within CDC and in 1986, Congress responded by appropriating $10 million to initiate a 3-year pilot program for the study of injury control at CDC.

The Injury Prevention Act of 1986 amended the Public Health Service Act, officially placing the injury control program at CDC. Subsequently, the Injury Control Act of 1990 (Public Law 101-558) reauthorized CDC's injury funding, and the National Center for Injury Prevention and Control was inaugurated in 1992 as the lead federal agency for nonoccupational injury prevention and control.

Through this locus in public health, the National Center for Injury Prevention and Control has developed a strong scientific base through intramural research and an extramural investigator-initiated grant program and has put prevention to work by supporting state and community injury control programs. Under CDC leadership, the field has grown, research has flourished, and effective programs have been identified and delivered to communities. Injury rates have fallen substantially in the United States since 1961; however, although effective strategies to prevent unintentional injuries are now widely recognized (*14*), they remain inadequately adopted.

TABLE. Haddon Matrix applied to motor vehicle injuries

Type	Host	Agent	Environment
Preevent	Alcohol use Fatigue Driving experience Defensive driving skill	Brake condition Load weight Vehicle visibility	Road curvature Weather Speed limit
Event	Seat belt use Bone density Stature	Speed at impact Vehicle size Vehicle safety features	Guard rails Median barriers Recovery zones
Postevent	Age Sex Frailty	Fuel tank integrity	911 access Triage protocols Emergency medical services training

Perspectives on Violence and Public Health

Thirty years ago, the words "violence" and "health" were rarely used in the same sentence. Today, violence is recognized as a major public health problem. Violence is defined as the intentional use of physical force or power, threatened or actual, against oneself, another person, or a group or community that either results in, or has a high likelihood of resulting in, injury, death, psychological harm, maldevelopment, or deprivation (*15*). This definition encompasses three broad types of violence: interpersonal violence (e.g., intimate partner violence, sexual violence, child maltreatment, elder maltreatment, and youth violence), self-directed violence (e.g., suicidal behavior), and collective violence (e.g., war, armed conflict, terrorism, and state-sponsored violence).

Several trends contributed to increased recognition and acceptance that violence could be addressed from a public health perspective:

- **Homicide and suicide rose in the rankings of causes of death** as the United States became more successful in preventing and treating infectious diseases. Since 1965, homicide and suicide have consistently been among the 15 leading causes of death in the United States (*16,17*).
- **The risk for homicide and suicide reached epidemic proportions during the 1980s.** Suicide rates among persons aged 15–24 years almost tripled during 1950–1990 (*18*). Similarly, during 1985–1991, homicide rates among 15- to 19-year-old males increased 154% (*19*). This increase was particularly acute among young African-American males.
- **The importance of behavioral factors was recognized** in the etiology and prevention of disease. Successes in applying behavioral strategies to changing other health risks encouraged public health professionals to apply these strategies to prevent interpersonal violence and suicidal behavior (*20*).
- **Child maltreatment and intimate partner violence were recognized** as social problems in the 1960s and 1970s, demonstrating the need to move beyond sole reliance on the criminal justice sector in solving these problems (*20*).

Public Health Call for Action

Several landmark reports highlighted the public health significance of violence. In 1979, the Surgeon General's report, Healthy People, identified 15 priority areas in which, with appropriate action, further gains could be expected during the next decade (*21*). Among the priorities was the control of stress and violent behavior. The goals for violence prevention established in this report were translated into measurable objectives in *Promoting Health/Preventing Disease: Objectives for the Nation* (*22*). These objectives called for substantial reductions by 1990 in the number of child-abuse injuries and deaths, reduction in the rates of homicide and suicide among persons 15–24 years of age, and improvements in the reliability of data on child abuse and family violence. In 1985, the *Report of the Secretary's Task Force on Black and Minority Health* identified homicide as a major cause of the disparity in death rate and illness by African Americans and other minorities relative to non-Hispanic whites (*23*). These themes were carried forward in subsequent versions of Healthy People 1990 and 2010 and, now, 2020.

Response to Healthy People Initiatives

The emergence of violence as a legitimate issue on the national health agenda spurred a variety of responses from the public health sector during the 1980s. In 1983, CDC established the Violence Epidemiology Branch, which was integrated into the Division of Injury Epidemiology and Control (DIEC) 3 years later. The creation of DIEC resulted directly from the Institute of Medicine report (*13*).

In 1985, the Surgeon General convened a workshop on violence and public health (*24*). This workshop marked the

first time that the Surgeon General encouraged all health professionals to respond to the problem. One recommendation from the workshop was an explicit call to include education about domestic violence in the curricula of medical schools and other relevant professional schools across the nation. Findings from the first survey to determine the prevalence of medical school instruction on domestic and other forms of family violence were summarized in *MMWR* in 1989 (*25*). In the same year, the *Report of the Secretary's Task Force on Youth Suicide* provided a comprehensive synthesis of the state of knowledge about youth suicide and recommended a course of action for stemming the substantial increases that had occurred during the previous 3 decades (*18*).

Applying the Tools of Epidemiology in Violence Prevention

During the same period, CDC undertook a number of epidemiologic investigations of a series of child murders in Atlanta and suicide clusters in Texas and New Jersey (*26–28*). These investigations helped to demonstrate that epidemiologic research methods could be successfully applied to incidents of violence. The suicide investigations also informed the first recommendations for preventing and containing suicide clusters issued by CDC and subsequent media guidelines for reporting on suicide (*27,29*).

Beginning in the early 1990s, the public health approach to violence shifted from describing the problem to understanding what worked in preventing it and increasingly began drawing on methods from the social and behavioral sciences (Box). CDC evaluation studies in the 1990s were among the first randomized controlled trials to specifically assess the effect of prevention programs on violence-related behaviors and injury outcomes among youth. These studies helped demonstrate that substantial reductions in aggressive and violent behavior were possible with applied, skill-based violence-prevention programs that address social, emotional, and behavioral competencies, as well as family and community environments. The achievements in the prevention of youth violence throughout the 1980s and 1990s were published in *Youth Violence: A Report of the Surgeon General* (*30*). The report also highlighted the cost-effectiveness of prevention over incarceration and set forth a vision for the 21st century.

The early successes in youth violence prevention paved the way for a public health approach to other violence problems, such as intimate partner violence, sexual violence, and child maltreatment. In 1994, CDC and the National Institute of Justice began collaborating on the first national violence-against-women survey, which produced the first national data on the incidence, prevalence, and economic costs of intimate partner violence, sexual violence, and stalking (*31*). In 1994, Congress also passed the Violence Against Women Act—landmark legislation that established rape prevention and education programs across the nation and called for local demonstration projects to coordinate the intervention and prevention of domestic violence. These programs were instrumental in building local- and state-level infrastructure and capacity for preventing intimate partner violence and sexual violence (Box).

BOX. Key primary prevention strategies for violence prevention

- Increase safe, stable, and nurturing relationships between children and their parents and caregivers.
- Enhance social, emotional, and behavioral development, and enhance opportunities for children and youth.
- Promote respectful, nonviolent intimate partner relationships through individual, community, and societal change.
- Promote individual, family, and community connectedness to prevent suicidal behavior.
- Reduce access to lethal means.
- Change cultural norms that support violence.
- Change the social, environmental, and economic characteristics of schools, workplaces, and communities that contribute to violence.

Source: References 15 and 20.

Global Focus

As public health efforts to understand and prevent violence gained momentum in the United States, they garnered attention abroad. Violence was placed on the international agenda in 1996 when the World Health Assembly adopted Resolution WHA49.25, which declared violence "a leading worldwide public health problem." The resolution requested that the World Health Organization (WHO) initiate public health activities to document and respond to the problem. In 2000, WHO created the Department of Injuries and Violence Prevention to increase the global visibility of unintentional injury and violence and to facilitate public health action. A framework for approaching violence as a public health problem was presented in the 2002 *World Report on Violence and Health* (*15*)—the first comprehensive examination of violence as a preventable global public health problem—and has been elucidated and expanded in subsequent reports, including the United Nations Secretary-General's *World Report on Violence Against Children* (*32*).

Perspectives on Trauma-Related Public Health

Care of the traumatically injured patient, with the explicit goal of reducing injury-related disability and death, is a clearly recognized public health priority. Access to health services, such as systems created for injury-related care, ranging from prehospital and acute care to rehabilitation, is among the most important strategies to reduce the consequences of injuries when prevention fails.

State of Trauma Care Before 1961

Until 1961, major clinical advancements in the care of acutely injured patients had resulted primarily from novel medical and scientific advancements. Wilhelm Rontgen and Alexander Fleming's discoveries of x-rays and penicillin, respectively, introduced into clinical practice radiography in injury diagnosis and antibiotics in the treatment of wound infections (*33,34*). Hemorrhagic shock experiments by Carl Wiggers led to acceptance of intravenous fluid resuscitation of the acutely injured patient (*35*). Although certain clinical management principles were recognized, nationally accepted guidelines addressing care for the injured patient were lacking, resulting in an absence of standardized practices or a systematic approach to improve survival. Since 1961, acute injury care in the United States has rapidly evolved, resulting in decreased disability and death. This success can be attributed, not to a single advancement in technology, but rather to a comprehensive, systems-based public health approach incorporating federal, state, and local governments and nongovernment stakeholders.

Key Developments in Trauma-Related Injury Since 1961

Development of Trauma Centers and Standardized Care

A major milestone in trauma-related public health was establishment of the first two U.S. trauma centers in 1966—one in San Francisco and the other in Chicago (*36*). These centers were developed to address increasing urban violence and marked recognition of the importance of systematic care for injured patients (*36*). This concept was furthered by R Adams Cowley, a U.S. Army trauma surgeon who established a Clinical Shock Trauma Research Unit in 1961 (*37*). In 1969, this unit developed into the Shock Trauma Center, the nation's first comprehensive health-care facility dedicated to trauma care. The Shock Trauma Center later became an autonomous clinical and research trauma institute. Cowley and colleagues subsequently developed a patient transportation and field communication system that became the first integrated, statewide trauma-response and emergency medical services (EMS) system in the United States (*37*).

Another milestone followed a plane crash in 1976, where orthopedic surgeon James Styner and his children were evacuated to a rural Nebraska hospital where they were treated by emergency department staff without specialized trauma training (*38*). Styner and his colleagues, motivated by the desire to standardize trauma care, produced the nation's first course in Advanced Trauma Life Support (ATLS), held in Nebraska in 1978 (*38*). Two years later, the American College of Surgeons (ACS) Committee on Trauma (COT) adopted ATLS and began national and international dissemination (*38*). After establishment of the nation's first two trauma centers and widespread ATLS adoption, ACS and several state and local agencies initiated a trauma center verification process for validating appropriate resources for optimal trauma care. In 1994, ACS-COT piloted a consultation process facilitating regional trauma system development. These consultations, modeled on a comprehensive public health approach, were highly effective in facilitating trauma system development, primarily in areas related to planning and system design (*39*).

The Effect of Military and Federal, State, and Local Government Involvement

The combat experiences of the U.S. military have played a substantial role in the development of trauma systems. The use of organized field medics during the Vietnam War served as a precursor for paramedics in civilian areas (*40*). Air medical transport of injured patients, first developed during World War I, became routine during the Korean and Vietnam wars (*40*). Lessons from routine air medical transport of soldiers in Vietnam fueled the rapid increase of civilian air transport of trauma patients in the United States during the 1980s (*41*). The conflicts in Iraq and Afghanistan led to further advances in military trauma care, which offer great promise for use in civilian settings. These include management of traumatic brain injury, use of hemostatic dressings and tourniquets, phased surgical approaches for complex injuries, and new approaches to resuscitation (*42*).

Legislation has been critical to the advancement of trauma care–related public health since 1961. The 1966 Federal Highway Safety Act mandated uniform guidelines improving EMS related to highway crashes (*43*). In 1973, the landmark Emergency Medical Services Systems Act established a program providing resources to state and local governments for implementing comprehensive EMS systems.

EMS providers and their medical directors use field triage decision schemes to assist with expeditious and appropriate transport decisions to regional trauma centers. These are a

combination of physiologic, anatomic, and mechanistic criteria intended to identify patients with, or at risk for, a severe injury. The first ACS-COT decision scheme was published in 1986 and revised three times (*44*). In 2005, CDC and its partners established the National Expert Panel on Field Triage to guide the 2006 revision of the field triage scheme. The 2006 Field Triage Decision Scheme, published by ACS-COT, was endorsed by 17 national organizations. CDC subsequently published these guidelines in *MMWR* in 2009 (*44*). Other federal agencies, including the Health Resources and Services Administration (HRSA) and NHTSA, have played a substantial role in developing public health interventions for trauma care. Trauma care and EMS resources directed at children were outlined in the 1984 HRSA Emergency Medical Services for Children Program (*43*). Additionally, in 1992, HRSA released the draft Model Trauma Care System Plan as a template for states in designing comprehensive trauma care delivery (*43*). In 1989, NHTSA developed a program to assist in coordinating state- and regional-level trauma-care resources.

The Need for Standardized Data Collection and Registries

Responding to the need for establishing a data coding, collection, and analysis system to guide clinical and public health practice, in 1967 the *International Classification of Diseases* (ICD) employed three- or four-digit codes to specify injury (*45*). Although potentially useful in recognizing injury incidence, ICD codes were not reliable for comparing injuries or describing severity. Recognizing the need for a comprehensive coding system to capture type, location, and severity of injury, a joint Committee on Injury Scaling, comprising members from the Society of Automotive Engineers, the American Association for Automotive Medicine, and the American Medical Association, published the *General Motors Collision Performance and Injury Report* in 1971 (*45*). This report described the Abbreviated Injury Severity (AIS) scale, which was the first widely adopted anatomical scoring system describing the threat to life associated with an injury (*45*). In 1974, the AIS scoring system was incorporated into the Injury Severity Score (ISS) to predict comprehensive injury mortality (*46*). In 1997, CDC guidelines on external mechanisms of injury were integrated and standardized with AIS to improve data quality, recording, and reporting (*47*). Both AIS and ISS marked a key step in the public health approach to trauma that allowed for public health practitioners to systematically approach and evaluate trauma prevention interventions, and outcomes.

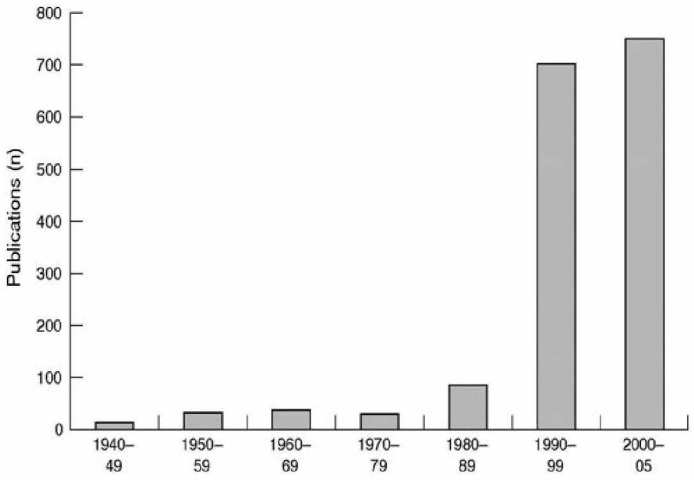
Trauma registries have been important for the care performance improvement process. These registries serve as repositories for data that can be evaluated, associated with outcomes, and used for quality control (*48*). In 1969, the first computerized trauma registry in the United States began in Chicago at Cook County Hospital. This system later evolved into the Illinois Trauma Registry and aggregated data from all trauma centers in the state. A milestone in the development of U.S. trauma registries came in 1989 with establishment of the National Trauma Data Bank (NTDB) by ACS (*48*). Since its inception, the National Trauma Data Bank has grown into the largest trauma data registry assembled with a large sample of trauma centers from across the nation.

The Next 50 Years in Injury Prevention, Violence Prevention, and Trauma Care

Substantial progress has been made since 1961 in recognizing unintentional injury and violence; developing trauma-care systems; developing a scientific base for the field; and discovering successful prevention measures. The tremendous growth in the field can be measured by number of publications by decade from <25 during 1940-1949 to approximately 750 during 2000–2005 (Figure 2). By end of 2011, the number of publications may well exceed 3,000. *MMWR* has been a critical partner in these efforts by providing a credible vehicle to share this scientific knowledge and its implications for practice with the media and the profession (*49,50*).

In the global arena, the *World Report on Violence and Health* (*15*), and the *World Report on Road Traffic Injury Prevention* (*51*) are now used throughout the world as platforms for prevention. *The Guidelines For Field Triage of Injured Patients* (*44*)

FIGURE 2. Number of publications in the field of injury prevention, 1940–2005



Source: Pless IB. A brief history of injury and accident prevention publications. Inj Prev 2006;12:65–6. Reprinted with permission from BMJ Publishing Group Ltd.

has become a widely adopted national tool and is increasingly being implemented in other parts of the world.

As the 21st century unfolds, public health is increasing its emphasis on the dissemination and implementation of effective injury and violence prevention programs and policies and tackling problems such as child maltreatment, youth violence, sexual violence, elder maltreatment, prescription drug overdose, alcohol-impaired and distracted driving, and falls among the elderly. Expanded use of treatment guidelines and effective trauma-care coverage will need to expand into rural and underserved areas and globally to enhance trauma-care systems in low- and middle-income countries (*52*).

One of the greatest challenges in the next 50 years will be to further change public attitudes and behaviors about the preventability of violence and unintentional injuries, just as public health has changed public attitudes to prevent tobacco use, sedentary lifestyle, and sexual risk-taking behavior. Unintentional injuries can no longer be considered "accidents." Violence can no longer be viewed as just a problem for the police or criminal justice sector. Evidence-based strategies uncovered in the last 50 years need to be disseminated and widely adopted in the next half century, and new strategies must be discovered to stem the tide of escalating injuries caused by prescription drug overdose, motorcycle crashes, falls by older adults, and the increasing popularity of motor-vehicle travel in low- and middle-income countries that lack appropriate safety systems.

Because most injuries are now considered preventable, the challenges lie in identifying those injury and violence winnable battles and in developing effective policies and delivering effective programs that can save many more lives. Achievements in injury and violence prevention and trauma care during the past 50 years have involved difficult professional and political struggles, and these struggles will continue during the next half century. The need for credible science, strong leadership, and strong partnerships will be more important than ever.

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Environmental Health in *MMWR* — 1961–2010

Henry Falk, MD
Consultant to Office of the Director, Office of Noncommunicable Diseases, Injury, and Environmental Health, CDC

Corresponding author: Henry Falk, MD, Office of the Director, Office of Noncommunicable Diseases, Injury, and Environmental Health, 4770 Buford Highway, Atlanta, GA 30341; Telephone: 770-488-0608; Fax: 770-488-0702; E-mail: hxf1@cdc.gov.

Introduction

As an epidemiology bulletin, *MMWR* has unique strengths and attributes. These include weekly publication (highlighting timeliness and frequency of reporting), rapid turnaround, a close relation with government practitioners of public health (federal, state, and local), and a clear mission of informing the public health community and the general public about new, reemerging, and ongoing threats to the public's health. With its integral relationship to CDC, *MMWR* also is a means of publishing major internal CDC reports, particularly surveillance reports.

The field of environmental health is particularly heterogeneous and diverse. Environmental threats can be categorized singly as particular toxins, chemicals, or risks (e.g., lead, mercury, dioxin, rats, and poisons), grouped by environmental media (e.g., air pollutants, water pollutants, and hazardous wastes), broadly demarcated by environmental place or setting (e.g., homes, communities, and rural environments), or more broadly by national versus global concerns. Similarly, environmental diseases can be categorized as diseases essentially caused by a specific environmental factor (e.g., heat stroke and carbon monoxide [CO] poisoning); diseases caused, triggered, or exacerbated by environmental risk factors (e.g., asthma); or chronic multifactorial diseases for which environmental risk factors are just one category of multiple risk factors (e.g., heart disease or cancer). Beyond disease, natural and human-made disasters (e.g., chemical, biologic, and nuclear/radiation), including terrorist events, are an essential focus of environmental health.

Given the attributes of *MMWR* and the breadth of environmental health, readers might anticipate that *MMWR* environmental health reports focus heavily on new or reemerging epidemic diseases, disaster situations, chemicals and toxins causing acute clinical illness, newly identified risk factors and threats for acute illness, and surveillance updates for tracking environmental disease. Indeed, such has been the case, particularly in *MMWR*'s early years; however, in recent years, coverage has broadened. This report provides an overview of *MMWR* as it related to environmental health during 1961–2010; the presentation of results follows the outline of the environmental framework (Table 1) and highlights the public health problems addressed in *MMWR*.

Methods

MMWR online listings were searched by title for all weekly reports broadly related to environmental health; prior years (1960–1964) were searched manually in the print-edition archives. Environmental concerns such as dietary supplements and other sources of toxic and hazardous exposures were included. Occupational exposures were not included, except in rare instances where both occupational and environmental exposures might be considered part of the same event or exposure.

A total of 826 reports were identified and categorized by their main topic for more detailed review (Table 1). Often, multiple ways existed to aggregate particular environmental problems, but the category that seemed most applicable was selected arbitrarily to enable discussion of topics in the sections believed to be most reasonable; for example, childhood lead poisoning from traditional home remedies is discussed with other sources of lead poisoning rather than with dietary supplements because those exposures are integral to understanding the distribution of lead poisoning cases. In contrast, eosinophilia-myalgia syndrome (EMS) is discussed under epidemic illnesses rather than under dietary supplements because EMS cases constituted a major national epidemic of a new disease and is best considered in that context.

All reports about a single topic or incident are counted separately. In this report, areas that were prominently featured in *MMWR* during the period are highlighted to provide a sense of how *MMWR* covered environmental health during that period.

Certain problems that intersect with environmental health were not included, either because they are covered elsewhere in this volume or because of size limitations in this report (e.g., refugee health or ultraviolet radiation and skin cancer).

Results

Environmental Disease

Poisoning and Illness from Ticks, Mushrooms, Plants, Snakes, Rats, and Other Factors (62 Reports)

These case reports and clusters were heavily represented in the early years of *MMWR*: 14 reports of tick paralysis, all but two before 1981 (the more recent reports emphasize the potential diagnostic confusion with Guillain-Barré syndrome); 24 reports of mushroom and plant poisoning (heavily focused on mushroom poisoning in the early decades, with isolated reports of poisoning from jimsonweed, moonflower, water hemlock, elderberry, and ostrich fern and plants containing belladonna alkaloids in recent decades); and nine reports related to snake bites, rat-bite fever, lionfish stings, arachnidism, sea urchin harvesting, and moth-related dermatitis. The purpose of these reports was to alert the reader to their occurrence and the potential for serious consequences. Fifteen additional reports were related to urban rat control (14 were quarterly surveillance reports for 1979–1982, highlighting the success of the existing CDC urban rat control program at that time).

Childhood Lead Poisoning (110 Reports)

During 1961–2010, the incidence, prevalence, mortality, and clinical severity of childhood lead poisoning dramatically declined. *MMWR* served both as an early reporting mechanism to document declining rates nationally and among groups at high risk and as a rapid-alert mechanism to highlight the various ways that children were exposed to lead (Table 2).

The first report in 1969 demonstrated high rates of lead poisoning, clinical severity, and fatalities in Newark, New Jersey, from exposure to lead paint (*1*); recent reports on lead paint have served as a reminder that, although much less common, severe effects and death still occur from lead paint ingestion. Early reports from El Paso, Texas (*2*), and Kellogg, Idaho (*3*), alerted the country to the striking exposures to children living near lead smelters; the most recent lead report of exposure in Zamfara, Nigeria (*4*), demonstrated high lead levels and high fatality rates from crude gold mining and smelting operations overseas. Other sources of lead exposure frequently addressed in *MMWR* included lead in dust taken home by workers exposed occupationally, lead in traditional home medicines administered to children, and lead exposure from incorrectly glazed ceramic ware; 21 types of exposure sources were identified from *MMWR* articles (Table 2). These reports probably make up one of the most detailed collections of the myriad ways in which children have been exposed to lead throughout the last 5 decades. New sources of lead poisoning continue to appear and are often published in *MMWR*. For example, imported charms and necklaces (and a host of other toys) with extremely high lead levels continue to be sold.

After establishment of the Childhood Lead Poisoning Control Program at CDC in 1973, a series of 32 quarterly surveillance reports during 1974–1982 demonstrated the buildup and success of that screening program. Reports in 1991–1992 spoke to the reestablishment of those screening programs.

A most critical function of *MMWR* has been the early release of national surveillance data from the National Health and Nutrition Examination Surveys (*5*) in 1982, 1994, 1997, and 2005 (more recent updates are in CDC's National Center for Environmental Health/CDC National Reports on Human Exposure to Environmental Chemicals). These reports have documented the dramatic and continuing decline of blood lead levels among children, from 88% of children in the United States with levels of ≥10 μg/dL in 1976 to 0.6% of children in 2010. The national trend data have been widely used by the U.S. Environmental Protection Agency (EPA), U.S. Department of Housing and Urban Development, CDC, individual states, and others in the development and evolution of programs to eliminate childhood lead poisoning. Additionally, *MMWR* has alerted readers to the issuance of new CDC screening guidelines, new lead legislation, and key reports from state and local health departments on regional and local lead health problems.

TABLE 1. Environmental framework/structural outline as applied to this *MMWR* review and number of *MMWR* articles for each topic* — 1961–2010

Category
Environmental disease
Environmental poisons (62), childhood lead poisoning (110), carbon monoxide poisoning (45)
New and reemerging epidemic diseases (30)
Asthma (26)
Environmental tobacco/secondhand smoke (21)
Environmental threats and risks
Specific chemicals (pesticides [28], metals [24], organic compounds [25]); substances of abuse (40); dietary supplements (18); consumer products (21); drugs/devices/therapeutics (12); other (3)
Media: water (60), air (13), food (46), hazardous wastes (14)
Places: homes, communities, global (47)
Disasters
Natural (volcanoes, tornadoes, heat waves, earthquakes, hurricanes, drought/famine) (153)
Biological/chemical/radiation/nuclear (4)
Terrorism: World Trade Center/other (24)

* Total number of *MMWR* weekly reports = 826.

TABLE 2. Source of exposure, number of reports, location of investigation, and date of publication for lead poisoning investigations reported in *MMWR* — 1961–2010

Source of exposure/risk factor	No. *MMWR* reports	State/location (no. reports)	October 7, 2011s
Folk remedies (primarily from Mexico and Asia)	10	CA (5); TX (2); CN, CO, FL, MA, MN, NH, NY (1 each)	7/9/2004; 8/9/2002; 1/22/1999; 7/16/1993; 9/8/1989; 11/16/1984;10/28/1983; 10/28/1983; 11/6/1981; 1/8/1982
Lead paint (fatalities, encephalopathy, and elevated exposures among children; home renovation and stripping paint)	8	NJ (3); NY (2); MA, NH, WI (1 each)	1/30/2009; 6/8/2001; 1/3/1997; 3/29/1991; 3/23/1979; 6/9/1978; 12/16/1977; 12/12/1970
Living near mining and smelting operations (El Paso, TX; Kellogg, ID; Zamfara, Nigeria)	7	TX (4), ID (2), Nigeria (1)	7/16/2010; 9/19/1997; 2/24/1978; 1/10/1976; 9/14/1974; 5/4/1974; 12/8/1973
Dust taken home from occupational exposure	7	CO (2); CA, ME, NC, TN, VT (1 each)	8/21/2009; 4/6/2001; 5/19/1989; 6/28/2005; 2/25/1977; 9/30/1977; 3/26/1976
Glazed ceramics	5	NY (2); AR, NJ, OR (1 each)	7/9/2004; 10/23/1992; 6/2/1989; 8/10/1974; 6/5/1971
Drinking water	4	DC (3); AZ, CA (1 each)	6/25/2010; 5/21/2010; 4/2/2004; 10/21/1994
Ingestion of charm/necklace	2	MN, OR (1 each)	3/31/2006; 6/18/2004
Imported candy from Mexico	2	CA (2); MI (1)	8/9/2002 (duplicate); 12/11/1998
Indoor firing range (student shooting team; National Institute for Occupational Safety and Health survey)	2	AK, multiple (1 each)	6/17/2005; 9/23/1983
Gasoline sniffing (tetraethyl lead exposure)	2	AZ, VA (1 each)	7/26/1985; 8/7/1981
Refugee children and adoptees (US)	2	NH, US (1 each)	1/21/2005; 2/11/2000
Chelation therapy-deaths from hypocalcemia	1	OR, PA, TX (1 each)	3/3/2006
Litarigio-antiperspirant/deodorant	1	RI (1)	3/11/2005
Dental offices	1	WI (1)	10/12/2001
Chewing plastic wire coating	1	OH (1)	6/25/1993
Moonshine/illicitly distilled alcohol	1	AL (1)	5/1/1992
Battery repair shop: living nearby	1	Jamaica (1)	7/14/1989
Intravenous amphetamine use	1	OR (1)	12/8/1989

Carbon Monoxide Poisoning (45 Reports)

Frequent MMWR reports on carbon monoxide poisoning have focused on surveillance updates (n = 14), primarily of U.S. mortality data, but also of emergency department rates and individual state data and on case or cluster reports (n = 3) that highlight the diverse ways that CO poisoning occurs. Guidance for prevention has been paramount in all of these reports.

The most recent reports on surveillance data, covering 1999–2004 (*6*), identified approximately 450 unintentional, nonfire-related poisoning deaths per year and 15,000–20,000 emergency department visits per year. A report in 1982 listed unintentional CO deaths of ≥1,500 per year.

The case/cluster reports can be grouped as follows:

1. Home-related (12 reports), all caused by incorrectly vented or malfunctioning gas-powered furnaces, hot water heaters, space heaters, or refrigerators. Also, incorrectly placed generators used during hurricanes and power outages frequently have been identified as a critical problem (see Natural Disaster section below).
2. Vehicle-related (nine reports), either caused by unvented indoor exhaust or close proximity to outdoor exhaust from vehicles, including automobiles, camper trucks, tractors, houseboats, motorboats, and ski boats. Two instances involved portable cook stoves brought inside enclosed camping tents for warmth at night.
3. Commercial buildings with heavy gas-fueled equipment (10 reports) (e.g., ice resurfacing machines in skating arenas, sporting events involving monster trucks and tractor pulls, and indoor power washers and floor polishers).

New and Reemerging Epidemic Diseases (30 Reports)

Perhaps the most prominent function of *MMWR* is to alert the public health community, as well as the general public, to rapidly evolving and unfolding events surrounding occurrence of epidemic diseases; this is particularly true for new diseases or unusual forms of previously known epidemic diseases (Table 3).

- **Angiosarcoma of the liver**. This illness manifested as a cluster of four cases of this extremely rare disease among vinyl chloride polymerization workers (*7*); the initial *MMWR* article in 1974 considered vinyl chloride monomer as the causative agent. Subsequent studies confirmed the causal association and detailed the pathogenesis that includes hepatic fibrosis and portal hypertension as precursor conditions (*8*); national surveillance identified three other known causes of this disease. Identification of vinyl chloride as a carcinogen after >3 decades of widespread use led to dramatic lowering of acceptable occupational

TABLE 3. New and reemerging epidemic diseases broadly related to environmental factors reported in *MMWR* — 1961–2010

Disease/syndrome	Date of initial report, location	Presentation	Date of follow-up reports
Hepatic angiosarcoma	2/15/1974, KY	Cluster of fatal liver cancer cases in vinyl chloride polymerization workers	6/21/1974; 7/25/1975; 3/5/1976; 2/7/1997
Toxic oil syndrome	5/25/1981, Spain	Atypical pneumonia, eosinophilia, and neuromuscular disease from illicit cooking oil	9/4/1981; 5/5/1982
Eosinophilia-myalgia syndrome	11/17/1989, NM	Eosinophilia, neuromuscular disease from L-tryptophan dietary supplement	11/24/1989;12/8/1989; 1/12/1990; 2/16/1990; 5/18/1990; 8/31/1990 (×2); 11/2/1990; 8/21/1991
Toxic hypoglycemic syndrome (Jamaican vomiting sickness)	1/31/1992, Jamaica	Profound hypoglycemia, vomiting, convulsions from ingestion of unripe ackee fruit	
Epidemic neuropathy*	3/18/1994, Cuba	Subacute optic and peripheral neuropathy likely from nutritional deficiency/tobacco smoking	
Renal failure†	8/2/1996, Haiti; 12/11/2009, Nigeria	Among children, from ingestion of diethylene glycol–contaminated acetaminophen syrup	
Acute idiopathic pulmonary hemorrhage among infants	12/9/1994, OH	Hypothesized/unproven association with water damage, mold, or fungi	2/3/1995; 1/17/1997;3/10/2000; 6/15/2001; 9/10/2004
Acute aflatoxicosis§	9/3/2004, Kenya	Jaundice from moldy, contaminated maize	
Gulf War illness	6/16/1995, Veterans	Unexplained illness/syndrome among Persian Gulf War veterans	

* CDC. Epidemic neuropathy—Cuba, 1991–1994. MMWR 1994;43:189–92.
† CDC. Fatalities associated with ingestion of diethylene glycol-contaminated glycerin used to manufacture acetaminophen syrup—Haiti, November 1995–June 1996. MMWR 1996;45:649–50; and CDC. Fatal poisoning among young children from diethylene glycol-contaminated acetaminophen—Nigeria, 2008–2009. MMWR 2009;58:1345–7.
§ CDC. Outbreak of aflatoxin poisoning—eastern and central provinces, Kenya, January–July 2004. MMWR 2004;53:790–3.

exposures and to greatly increased protection of the general population potentially exposed to vinyl chloride in different ways. The follow-up articles examined geographic clusters of these cases in Connecticut and Wisconsin and congenital malformations in two communities near production facilities; those reports did not link community environmental exposures to these findings. In 1997, as part of the celebration of CDC's 50th anniversary, MMWR reprinted the original 1974 report and a new editorial note (*9*).

- **Toxic oil syndrome.** The initial *MMWR* article, published in 1981, described approximately 1,300 persons in Spain hospitalized for atypical pneumonia of uncertain etiology (*10*). The second report, also published in 1981, documented that approximately 12,000 persons were hospitalized and included results of a case-control study that determined the epidemic's causative vehicle, illicit cooking oil sold by itinerant peddlers in unmarked bottles (*11*). The final article, which was published in 1982, one year after the start of the epidemic, characterized the decrease in new cases after protective actions and described the evolution of the disease into a chronic phase with pronounced neuromuscular and other findings (*12*). Although approximately 25,000 persons experienced this new disease, the specific etiologic agent was never identified (*13,14*).
- **Eosinophilia-myalgia syndrome.** The initial *MMWR* article, published in 1989, described three index patients in New Mexico with eosinophilia-myalgia syndrome (EMS) who had used L-tryptophan dietary supplements, and a preliminary report of additional cases in the state also was linked to ingestion of L-tryptophan (*15*). By the following week, *MMWR* was able to report results from four states that included two case-control studies linking illness with specific lots of L-tryptophan (*16*). Subsequent reports provided updates from national surveillance, added to knowledge about the clinical spectrum, and provided interim findings on potential contaminants in the L-tryptophan (*17*). With nine updates in <1 year, *MMWR* provided timely reporting of this rapidly developing epidemic. From the first report, *MMWR* also noted the clinical similarity of EMS to toxic oil syndrome.

Asthma (26 Reports)

All *MMWR* articles related to asthma appeared after 1989, and the majority related to asthma surveillance. *MMWR* articles have covered such topics as asthma deaths and hospitalization among adults and children and self-reported illness through the Behavioral Risk Factor Surveillance System (*18*). Selected reports have evaluated health-care use (e.g., use of inhaled medication and state and local programs). Asthma triggered by specific chemicals and events are covered elsewhere in this report.

Environmental Tobacco/Secondhand Smoke (21 Reports)

Almost all *MMWR* articles on environmental or secondhand tobacco smoke have appeared since 2000. Articles have covered

such topics as biomonitoring data from the National Health and Nutrition Examination Survey, which has tracked cotinine levels among U.S. nonsmokers; levels have declined significantly during the past two decades—from a prevalence of 88% ≥0.05 ng/mL in the population aged ≥4 years (1988–1991) to 40% in the population aged ≥3 years (2007–2008) (*19*). Other *MMWR* articles have covered exposure to secondhand smoke as reflected in data from the Behavioral Risk Factor Surveillance System and other surveys.

A particular focus of *MMWR* has been the impact of state and local policies to reduce smoking in indoor worksites and in public places (e.g., the New York State comprehensive ban for such sites); undoubtedly, successful implementation of these policies has been a major reason for declining exposures. A recent *MMWR* report took this one step further by noting reduced hospitalization for myocardial infarction after implementation of a smoke-free ordinance in the city of Pueblo, Colorado.

Environmental Threats and Risks

Specific Chemicals, Toxins, and Risk Factors

Over the years, *MMWR* has published reports on the adverse effects of a wide array of chemicals (metals, organic compounds, and pesticides); dietary supplements; consumer products; drugs, devices, and therapeutics; and substances of abuse (Table 4 and 5). Most appear as single reports and covering them all here is not possible. Certain especially instructive reports from each category are mentioned below.

Pesticides (28 reports)

Almost all the *MMWR* reports focused on acute toxicity from inappropriate, unintended, or extremely high exposures. Reported illnesses and deaths included those from fumigants resulting from offsite drift from agricultural use of chloropicrin soil fumigant, phosphine release in a fumigated railroad boxcar, home fumigation with sulfuryl fluoride, and soil fumigation with methyl bromide. *MMWR* reported a widespread outbreak of food poisoning from aldicarb contamination of melons that occurred in California in 1985 (*20*); subsequent reports described poisoning from the illegal use of aldicarb as a rodenticide and from its mistaken use in food preparation. Illnesses and fatalities were reported from inappropriate use of methyl parathion for insecticide control in a home environment with multiple possible routes of exposure to children; a much earlier report from 1970 described poisoning among teenaged boys harvesting tobacco. Two widespread outbreaks of food contaminated with endrin were reported from Pakistan (*21*) and the Middle East.

Metals (24 reports)

The vast majority of *MMWR* reports on metals were related to mercury. The largest number addressed individual instances of elemental mercury exposure in homes, schools, or neighborhoods. Multiple reports detailed exposure investigations with potentially broad implications (e.g., identification of elevated mercury exposure from use of interior latex paint that led to changed regulations for such paints [*22*] and mercury poisoning among Hispanics in the Southwest from use of beauty creams produced in Mexico [*23*]). Articles on the challenges of addressing long-term exposure to low levels of toxins among vulnerable populations appeared only rarely; one such report contained a joint statement of the American Academy of Pediatrics and the U.S. Public Health Service on exposure to thimerosal in vaccines (*24*).

Organic compounds (25 reports)

The largest number of *MMWR* reports on organic compounds related to polychlorinated biphenyl (PCB) and dioxin exposures. The PCB-related reports were primarily about instances of high-level, acute exposures (e.g., from transformer fires and food contamination episodes). The dioxin reports focused on multiple prolonged inquiries into long-term effects of dioxin exposure among Vietnam War veterans, Missouri residents exposed to dioxin in soil, and residents near the release of dioxin by a chemical explosion in Seveso, Italy (*25,26*). Reports on dioxin exposures represented the infrequent instances in which *MMWR* published reports on the problem of long-term consequences of chemical exposure.

Substances of abuse (40 reports)

Reports related to substances of abuse frequently have been featured in *MMWR* throughout the past five decades. The reports often have related to specific episodes of apparently increased rates of overdoses and fatalities; reports have documented incidents where such increases were related to contaminants (e.g., cocaine containing the antihelminthic drug levamisole or heroin contaminated with scopolamine or clenbuterol). The most dramatic example was the identification of Parkinsonism after exposure to the street drug 1-methyl-4-phenyl-1,2,3,6-tetrahydropyridine, a potent analogue of meperidine (*27*). As noted elsewhere in this report, the reports from the Hazardous Substances Emergency Events Surveillance (HSEES) system on the acute public health consequences of methamphetamine laboratories have had a strong public health impact (*28*).

TABLE 4. Adverse effects of pesticides, metals, organics, and other exposures reported in *MMWR* — 1961–2011

Pesticides (no. reports)	Metals (no. reports)*	Organic compounds (no. reports)	Other (no. reports)
Methyl parathion (4)	Mercury (21), including elemental mercury, thimerosal, organic mercury, and beauty cream	Dioxin (8); including in Vietnam War veterans; Missouri soil; and Seveso, Italy	Asbestos soil exposure (1)
Aldicarb (3)	Thallium (2)	Polychlorinated biphenyls (PCBs) (7)	Radiation (2)
Endrin (3)	Arsenic (1)	Polybrominated biphenyls (PBBs) (2)	
Mosquito control spray (3)		Dichlorodiphenyltrichloroethane (DDT) (2)	
Fumigants (3)		Trichloroethylene (TCE) (1)	
Diazinon (2)		Gasoline spill (1)	
Lindane (1)		Biodiesel, home production (1)	
Rodenticide containing TETS (1)		Toluene diisocyanate (1)	
DEET (1)		Compounds at Love Canal, Niagara Falls, New York (1)	
Sulfuryl fluoride (1)		1, 3-dichloropropene (1)	
Chlorpyrifos (1)			
Carbophenothion (Trithion) (1)			
Organophosphates, multiple (4)			

*Not including lead poisoning and selected problems highlighted elsewhere in this report.

TABLE 5. Adverse effects of substances of abuse, dietary supplements, consumer products, drugs, devices, or therapeutics reported in *MMWR* — 1961–2011

Substances of abuse (no. reports)	Dietary supplements and unorthodox remedies (no. reports)	Consumer products (no. reports)	Drugs, devices, and therapeutics (no. reports)
Heroin (8)	Asian traditional remedies (4), including Chinese (3) and Hmong (1)	Aerosolized carpet shampoo and aerosol conditioner for shoes, boots, and leather products (4)	Nasopharyngeal radium irradiation/head and neck cancer (1)
Marijuana (6)	Herbal teas (3), including Kombucha, senna cathartics (1), foxglove (1), and pyrrolizidine alkaloids (1)	Hexachlorophene baths and newborn neuropathology (4)	Benzyl alcohol preservatives/neonatal deaths (1)
Cocaine (5)	Selenium (1)	Neonatal toxicity from use of phenolic laundry detergents in neonatal nursery (3)	Diidohydroxyquin-induced blindness (1)
Methamphetamine (5)	High-dose vitamin A (1)	Pentachlorophenol exposure in log cabins (2)	Prilocaine-induced methemoglobinemia (1)
Gamma-Hydroxybutyric acid (2)	Turpentine/castor oil (1)	Limes and phototoxic dermatitis (1)	Ephedrine and cryoglobulinemia vasculitis disease (1)
Isobutyl nitrite (1)	Chaparral (1)	Butyl caulk and toluene toxicity (1)	Cyanide tampering of Sudafed® (1)
Ecstasy (1)	*Gamma*-butyrolactone as source of *gamma*-hydroxybutyrate (date-rape drug) (1)	Naphthalene toxicity from mothballs (1)	Sporicidin device sterilant (1)
General/multiple (12)	Kava (1)	Indoor paint containing Bis (tributyltin) oxide (1)	Undiluted 25% intravenous human albumin and hemolysis (1)
	Herbal supplement with aretemisinin (1)	Chlorine gas generated by mixing bleach with commercial phosphoric acid cleaner (1)	Halofantrine and sudden death (1)
	Pennyroyal oil (1)	Household lamp oil ingestion and toxicity (1)	Colchicine overdose from pharmaceutical compounding error (1)
	Raw carp gallbladders (1)	Spray adhesive use in pregnancy (1)	Gadolinium contrast agent and renal disease (1)
	Mesotherapy (1)	Digoxin-containing aphrodisiacs and death (1)	Soluble barium sulfate contrast solution and overdose deaths (1)
	Silicone filler injections (1)		

Dietary supplements (18 reports)

MMWR reports have appeared on lead poisoning from Asian traditional home remedies (discussed previously under childhood lead poisoning), arsenic poisoning from Hmong traditional remedies, agranulocytosis from a phenylbutazone-containing Chinese herbal remedy, and two reports of toxicity from a traditional Chinese remedy called Jin Bu Huan. The *MMWR* report on ingestion of raw carp gallbladders leading to acute hepatitis and renal failure is one of the most unusual food-related articles in this group.

Consumer products (21 reports)

The *MMWR* articles about consumer products constitute another remarkable collection of acute toxicity and fatalities related to unintended consequences from use of different types of products (e.g., death from digoxin-containing aphrodisiacs [*29*]). One recurring theme was toxicity from aerosol boot, shoe, and leather conditioner or sealants, with rapid identification of cases leading to product recalls. Another important theme was outbreaks of acute illness and death in neonatal nurseries during the predisposable diaper period (1960s–1970s): strong phenolic laundry detergents left residues that were absorbed through the skin of vulnerable newborns, leading to severe toxicity (*30*).

Drugs, devices, and therapeutics (12 reports)

This group comprises dramatic reports of rarely experienced toxicity and death from substances. It includes intentional cyanide poisoning from deliberate tampering with over-the-counter medications (*31*), severe toxicity and deaths among newborns exposed to benzyl alcohol preservatives in intravenous solutions, and severe barium toxicity from use of an absorbable barium salt for radiologic examinations (*32*).

Environmental Media

Water (60 reports)

Approximately half of the *MMWR* reports on environmental media related to recreational water–associated illness and its prevention. The strong environmental components in these reports emphasized such concerns as swimming pool and public spa inspections and guidelines (*33*) and injuries and illness from incorrectly used pool chemical disinfectants and chloramine vapors. Chemical contamination of drinking water was reported 10 times, from chlordane, nitrates/nitrites, sewage, phenol, caustic soda, and ethylene glycol; all of these involved elevated exposures and sometimes illness as well (e.g., methemoglobinemia from nitrite exposure). Other environmental aspects included red tides, Pfiesteria spp., fluoridation, outbreaks of disease related to Clostridium spp. and other waterborne microbes, and one report on inadequately filtered public drinking water. Only a few articles related to regulatory standards for chemicals in drinking water.

Air (13 reports)

For a brief period after reauthorization of the Clean Air Act in 1990 and the release of *Healthy People 2000* (*34*), a flurry of *MMWR* articles focused on the national impact of air pollution, particularly on the numbers of persons residing in counties exceeding EPA air standards and on the air pollution problems facing state and local health departments. *MMWR* coverage on this topic slowed after 1995.

Food (46 reports)

Eleven reports on surveillance and FoodNet (available at http://www.cdc.gov/foodnet/) focused primarily on trends of outbreaks and illness related to specific microbial sources. An article on safer and healthier foods, published as one of *MMWR*'s series on achievements in public health throughout the 20th century, emphasized the role of environmental advances (e.g., refrigeration and pasteurization). During 1960–1979, a total of 21 reports appeared on food poisoning from metals (copper, cadmium, antimony, zinc, chromium, and calcium), and seven more from nitrites, monosodium glutamate, and fluoride, primarily related to contamination of food from faulty equipment, incorrect preparation technique, or mistaken ingredients. Six more recent reports described unusual exposures (e.g., ammonia contamination of milk, niacin intoxication from bagels, and nicotine poisoning from ground beef).

Hazardous wastes (14 reports)

During the early 1990s, soon after the creation and establishment of the Agency for Toxic Substances and Disease Registry, *MMWR* published a short series of reports and alerts related to developments at that agency (e.g., a statement on the agency's priority health conditions and research strategies) and a short summary of the report on the public health implications of medical waste.

During the past six years, six reports have summarized findings from the Hazardous Substances Emergency Events Surveillance (HSEES) system (e.g., on hazardous substances released during rail transit in 18 states during a six-year period [*35*]) and on hazardous chemical incidents in U.S. schools for a six-year period. Certain of these HSEES reports on chemical releases and explosions in methamphetamine laboratories helped policymakers more closely regulate these illicit production facilities (Table 6).

Environmental Places

Healthy homes, healthy communities, and global environmental health (47 reports)

MMWR articles often include information about homes, communities, and global health, usually in the context of a specific problem (e.g., lead poisoning and asthma; hazardous waste disposal; and earthquakes, drought, and famine). During 1961–2010, five reports were related to homeless persons, usually in association with alcohol and substance abuse as risk factors for death, and five reports focused on elevated radon levels in homes. The built environment was a focus of nine reports, most of which considered how environmental features can promote physical activity among adults and children. Environmental features of infectious diseases figured prominently in 17 reports related to outbreaks on cruise ships (e.g., one report documenting the preventive role of regular ship inspections) and in 11 reports related to Legionnaires disease.

Disasters

Natural disasters (153 reports)

Before 1980, *MMWR* rarely reported on natural disasters; reports have escalated rapidly since then (Table 6). The increase undoubtedly reflects growing engagement by the public health community generally, and by CDC specifically, in disaster preparedness and response. At CDC, this corresponds to the creation of the National Center for Environmental Health in 1980 and its establishment of emergency response and disaster epidemiology units, as well as to the more recent creation of CDC's Office of Terrorism Preparedness and Emergency Response (now the Office of Public Health Preparedness and Emergency Response). The increase in natural disaster reports in *MMWR* has varied by the type of event: volcano reports essentially focused on Mount St. Helens in 1980; tornado reports peaked during the 1980s and 1990s; heat wave reports have been fairly level for the past three decades; and hurricane-related reports have increased steadily throughout the past five decades. This section highlights the findings in six of the most numerous categories. Most of the reports related to U.S. disasters; however, the drought and famine category was global, and the earthquake category mostly so.

- **Volcanoes.** Mount St. Helens came to life with a major eruption on May 18, 1980 (*36*); *MMWR* published a sequence of 14 reports to provide public health updates and recommendations. This series was a landmark in *MMWR's* initiating intense engagement on natural disasters; in addition to the *MMWR* sequence of reports, an *MMWR* report published on July 11, 1980, listed a series of 33 technical information bulletins from the Federal Emergency Management Agency. The health bulletins were all based on 23 Mount St. Helens volcano health reports from CDC that continued through February 1981 and were widely distributed throughout the Pacific Northwest. Both *MMWR* short summaries and the more detailed volcano reports covered a wide array of actual and potential health impacts (e.g., illness and death; respiratory health; safety for cleanup workers and loggers; impact on water systems and other key infrastructure; testing for toxic chemicals in the ash; levels of ash fall and monitoring of volcanic activity; and potential for long-term respiratory effects, including pneumoconiosis [*37*]).
- **Tornadoes.** The group of nine *MMWR* articles on tornadoes began with a landmark report of a 1979 tornado investigation in Wichita Falls, Texas; 44 persons were killed and 171 were hospitalized for injuries (*38*). Guidance regarding seeking shelter was reaffirmed; however, existing guidance on how to drive out of harm's way was demonstrated to be futile and led to updated recommendations. Subsequent reports highlighted the vulnerability of mobile homes and the need for shelter areas in mobile home parks, the frequent inadequacy and failure of warning systems and sirens, and guidance for adequate sheltering and protection from injury and death. The last report specifically on tornadoes was published in 1997.
- **Heat waves.** The heat wave of summer 1980 led to descriptive epidemiologic and case-control investigations in St. Louis and Kansas City, Missouri. A total of 784 deaths and severe illnesses were attributed to the heat. In another landmark study that changed longstanding public health practice, the results demonstrated that even short periods in an air-conditioned environment were protective, whereas the then-common practice of distributing fans during heat waves was counterproductive. Because the sweating mechanism is compromised during the early stages of heat illness, delivery of hot air by fans exacerbates the situation (*39*). Reports of the Chicago heat wave in 1995 and of the heat wave in Europe in 2003 emphasized the vulnerability of older persons, infirm persons, and persons in socioeconomically deprived circumstances (*40*); multiple reports affirmed the effectiveness of having relief workers mobilize older persons for trips to air-conditioned environments (e.g., shopping malls). Recent reports also have highlighted other vulnerable groups for heat illness (e.g., farm workers and high school athletes).

  To provide timely public health guidance before the winter and summer seasons, MMWR has published approximately two dozen articles about hyperthermia and hypothermia, usually timed to appear before the winter or summer season begins. These reports have provided summary statistics on heat- and cold-related

TABLE 6. Number of *MMWR* articles related to natural disasters, by decade — 1961–2010

Category	1961–1970	1971–1980	1981–1990	1991–2000	2001–2010	Total
Hurricanes			5	9	32	**46**
Heat waves	1	2	6	9	8	**26**
Extreme cold			4	7	7	**18**
Volcanoes		12	2			**14**
Earthquakes		1	3	2	6	**12**
Tornadoes		1	3	5		**9**
Winter storms/snow			1	6	1	**8**
Floods			2	5		**7**
Drought/famine			5	1	1	**7**
Lightning				1	1	**2**
Wildfires					2	**2**
General			1		1	**2**
Total	**1**	**16**	**32**	**45**	**59**	**153**

deaths in the United States, instructive case reports from multiple states highlighting risk factors, and updated public health guidance.

- **Earthquakes.** Reports have focused on assessments of mortality and morbidity (Italy, 1981; Loma Prieta, California, 1989; Philippines, 1990); coccidioidomycosis after the Northridge, California, earthquake in 1994; health-related needs assessments linked to response or surveillance (Turkey, 1999; Indonesia and Thailand tsunami, 2004), victim identification (Thailand tsunami, 2004), and surveillance (Haiti, 2010). These largely have been acute-phase reports related to early assessments of the magnitude of the problem and the extent of acute public health needs.
- **Hurricanes.** Hurricanes have been increasingly the most commonly reported category of natural disaster published in *MMWR*, although approximately half of all such reports (22/46) related to Hurricane Katrina. For the reports not related to Hurricane Katrina or Hurricane Rita, four major themes are apparent:
  - — Needs assessment surveys were reported in *MMWR* for Hurricanes Ike, Wilma, a cluster of Florida hurricanes in 2004 (three articles), Allison, Georges, Marilyn and Opal, and Andrew (two articles). Needs assessments usually targeted vulnerable groups (e.g., older persons or rural populations).
  - — CO poisoning from unsafe generator use was reported for Ike and the Florida cluster; also, one report involved dry ice–induced CO poisoning in the 2004 Florida cluster.
  - — Medical examiner mortality data were analyzed and reported in *MMWR* for the 2004 Florida cluster, Floyd, Marilyn and Opal, Andrew, and Hugo (two articles).
  - — Surveillance data were reported for illness and injury rates at Marilyn and Opal, Hugo, and Elena and Gloria. The only other reports were related to mosquito-control efforts at Andrew and evaluation of postdisaster work-related electrocutions from downed power lines after Hugo.

  Katrina was much more complex for multiple reasons, including the devastating destruction and flooding over multiple states, the approximately one million evacuees, the long time frame for restoring basic functions and repopulating New Orleans, and the extended periods spent by thousands of persons in shelters and temporary trailers. For Hurricane Katrina, four reports were published about rapid needs assessment, three on CO poisoning, one on mortality, and seven on surveillance for injury and illness in health-care facilities and evacuation centers. Reports related to the special features of Katrina included information about relief workers and occupational guidance, the ubiquitous mold problem, a norovirus outbreak in a shelter, two cases of toxigenic *Vibrio chlolerae* O1, and the substantial number of tuberculosis patients temporarily lost to follow-up during the chaos of the evacuation.
- **Drought and famine.** All seven reports describe investigations of major drought impact in Africa (Niger, 2005; Ethiopia, 2000; Somalia, 1987; Niger 1985; Burkina Faso, 1985; Chad, 1985; and Mauritania, 1983). These reports described collaboration among CDC, the U.S. Agency for International Development, United Nations' agencies (e.g., UNICEF), and country governments. These reports also described surveys that were conducted of children as the most vulnerable group, and relief efforts focused on nutritional status, respiratory and gastrointestinal disease, measles vaccination, and vitamin A and C deficiencies.

Biologic, chemical, radiation, and nuclear (four reports)

During 1961–2010, several additional reports were related to potential adverse effects of chemical warfare agents. With the growth of environmental programs at CDC—the National Center for Environmental Health was created shortly after, and largely as a result of, the 1979 Three Mile Island event—readers might anticipate more complete coverage of such events in the future. Perhaps as a reflection of that, the most recent *MMWR* covered in this report relates to radiologic and nuclear preparedness and summarizes a CDC Grand Rounds session (*41*); additional reports relate to potential adverse effects of chemical warfare agents.

Terrorism

World Trade Center attack (15 reports)

The sequence of 15 *MMWR* articles after the September 11, 2001, terrorist attacks was the second largest series of reports related to a single environmental event. The initial overview of activities in response to the attacks appeared on September 28, 2001 (*42*). Six of the reports related to occupational concerns: exposures to workers at and near the site, injury and illness rates among workers, use of respiratory protective equipment, and follow-up of first responders' mental and physical health. The themes of the initial environmental reports were similar to those in other disaster settings: community needs assessment; investigations of deaths; and surveillance for injuries and illness, including a review of syndromic surveillance (*43*). A pilot survey of airborne and settled dust in residences did not find evidence of substantive asbestos exposure, although dust of pulverized building materials was present (*44*). Follow-up reports tracked residents' respiratory and mental health. Subsequent publications have addressed these findings more

fully and documented the elevated rates of new-onset asthma and posttraumatic stress disorder; the World Trade Center Registry was instrumental in enabling a thorough evaluation of these concerns (*45*). The ability to publish approximately a dozen detailed and pertinent follow-up reports about critical aspects of this disaster in less than a year demonstrates the unique value of *MMWR* to meet the need for accurate and timely information after such disasters.

Discussion

This review of 826 *MMWR* articles demonstrates the scope of *MMWR's* coverage of environmental health and the remarkable diversity and richness of the field. Over five decades, MMWR has reported on hazards and diseases both old and new. A reader of these reports is struck by all the ways that old and well-known hazards can resurface under unanticipated circumstances. For example, the *MMWR* reports on lead and CO poisoning and pesticides are full of new exposure pathways that constantly surprise. *MMWR* has been an excellent resource for highlighting and tracking surveillance data for environmental diseases (e.g., lead poisoning, CO poisoning, and asthma) and for reporting biomonitoring results that demonstrate population exposure trends for cotinine, lead, mercury, and other substances.

MMWR has been at its best in highlighting and tracking new outbreaks of disease, unfolding disasters (both natural and human-made), urgent public health scenarios, and the multiple ways in which illness and death can occur from exposures to chemicals and hazards. It is a unique resource for timely updates of major events (e.g., Mount St. Helens; Hurricane Katrina; the 2001 attack on the World Trade Center, and epidemics, including the outbreak of EMS). It is an effective way to provide preliminary reports of complex investigations that highlight important public health messages (e.g., with the 1980 heat wave investigation or the toxic oil syndrome investigation). Additionally, it likely represents the most remarkable collection of reports on outbreaks, illness, and death in existence from pesticides to natural poisons, dietary supplements, home remedies, chemicals, and consumer products.

Over its five decades at CDC, *MMWR* reports on environmental health have focused mostly on acute, high-dose, clinically apparent, and urgent risks. This analysis of MMWR reports over 50 years shows this repeatedly — scores of reports on acute outbreaks related to water pollutants, pesticides, and CO. During the 50 years, *MMWR* has focused much less on chronic, long-term risks from repeated low-level exposures and the policy and regulatory approaches that society employs to protect the public from such risks. This is understandable given that the *MMWR* weekly, with its traditional short, telegraphic form, was created to report on immediate threats to the public health. Authors have generally recognized that, for analyses that require more complex epidemiologic analyses and description, long-form peer-reviewed medical and public health journals are a more conducive forum, although the *MMWR* Surveillance Summaries do publish long-form compendiums of surveillance findings.

In recent years, this has begun to change as authors of longer-term studies have wished to capitalize on *MMWR's* appeal to the news media and the nation's public health readership. Even with its short format, the *MMWR* weekly now often publishes reports on long-term public health exposures and resultant illnesses, or on health behaviors. In *MMWR's* next 50 years, as it continues to cover the field of environmental health and as that field increases in importance even beyond its current state, *MMWR* might consider periodic (i.e., monthly or quarterly) reports on environmental health policies, risk analysis, regulatory approaches, long-term epidemiologic studies, or other areas that can be meaningfully presented to the broader public health community. This might further enhance the critical value of *MMWR* to the field of environmental health.

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Occupational Epidemiology and the National Institute for Occupational Safety and Health

William Halperin, MD, DrPH[1]
John Howard, MD, JD[2]
[1]*Department of Preventive Medicine and Community Health, New Jersey Medical School, University of Medicine and Dentistry of New Jersey, Newark, New Jersey*
[2]*Office of the Director, National Institute for Occupational Safety and Health, CDC, Washington, D.C.*

Corresponding author: William Halperin, MD, DrPH, Department of Preventive Medicine and Community Health, New Jersey Medical School and School, 185 South Orange Avenue, MS8, Room F-506, P.O. Box 1709, Newark, NJ 07101-1709; Telephone: 973-972-4422; Fax: 973-972-7625; E-mail: halperwe@umdnj.edu.

Introduction

The major factors that propelled the development of occupational epidemiology since the 1950s have been delineated (*1*). They include momentum to control occupational injury that gained national prominence in the wake of the Triangle Shirtwaist Fire of March 25, 1911, in which 146 young, mostly female immigrant garment workers fell to their deaths while escaping from a fire in a locked sweat shop. This tragedy was a turning point in the nationwide adoption of state-based occupational safety regulations, workers' compensation programs, and federal safety legislation. During the 1930s, federal initiatives in occupational safety and health required contractor compliance, not only with wage and hour laws, but also with federal occupational safety and health regulations. The New Deal built state capacity by funding state industrial hygiene programs. Levenstein (*1*) reports a diminution of interest in occupational safety and health, except for the Atomic Energy Act in the 1950s, until the 1960s' resurgence in organized labor's political voice. Also, societal reaction to the Farmington, West Virginia, mine disaster of 1968, which killed 78 miners, led to passage of the Federal Coal Mine Health and Safety Act of 1969 and introduced federal regulation and federal inspectors to the mining industry.

To this brief history could be added the major scientific advances in the invention and commercialization of synthetic organic chemicals, such as organic dyes that caused epidemics of bladder cancer among industrial workers and anemia and leukemia among benzene-exposed workers. Interest among health-care students and the public probably was affected by growing concern about the health effects of environmental toxins communicated to the public through Rachel Carson's 1962 book, *Silent Spring* (*2*). This book vividly detailed the environmental consequences of pesticides and helped launch the environmental movement. In 1965, a parallel popular book by Ralph Nader, *Unsafe at Any Speed* (*3*), concerned the forces at play in industry and society that led to production of unsafe automobiles and failure to adopt new safety technology, such as seat belts, which vaulted consumer safety into the public agenda. These historical tides provided fertile ground for national-level development of occupational epidemiology midway through the 20th century.

The institutional genealogy and political history of the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH) through numerous government predecessor organizations has been delineated by Lynne Page Snyder (L.P. Snyder, *The National Institute for Occupation Safety and Health, 1971–1996: a brief history*. Office of the Public Health Service Historian, 1997, unpublished data). The capstone event for occupational health in the mid-20th century was passage of the Occupational Safety and Health (OSH) Act, supported by President Lyndon Johnson as part of the New Society and signed into law on December 29, 1970 by President Richard Nixon, the son-in-law of a miner who died of silicosis. Congress provided a broad delegation of authority to the Secretary of Labor to carry out the OSH Act. The OSH Act federalized regulation and enforcement, including inspections that had previously been a function of various state governments, and provided for the first time uniform national enforcement of occupational safety and health across the United States. It removed responsibility for inspection and enforcement from state governments—which sometimes were conflicted in balancing the interests of health and safety against those of commercial enterprise and local politics. The OSH Act also mandated that the federal government gather a critical mass of scientific expertise across multiple disciplines, such as medicine, epidemiology, industrial hygiene, safety, health education, and psychology, to focus exclusively on occupational disease and injury prevention.

The OSH Act also reshaped the playing field with regard to epidemiologic investigations. The first change was in providing workers or their representatives and management with experts who could assess the potential for, or occurrence of, occupational disease and injury in their workplaces. Before the

OSH Act, the playing field in many states was far from level. Employers, especially larger corporations, had the resources to provide access to occupational health consultants and epidemiologists. It would have been unusual for organized labor and much less likely for nonunion workers at smaller workplaces to have the resources to hire such experts. The OSH Act gave them access to epidemiologic consultation, which was called a Health Hazard Evaluation (HHE), and the Act was worded to give them direct access to expertise in the federal government, thereby bypassing state and local government. The impact of the NIOSH HHE program was that both workers and management gained unhindered access to multidisciplinary occupational health expertise. Workers and small employers were no longer prevented from obtaining this expertise by an inability to pay. Also, perhaps most importantly, worksite problems would now be approached by using a public health and consultative perspective.

Parallel considerations also led to inclusion in the OSH Act of research expertise in epidemiology, toxicology, and other fields. This expertise would provide unbiased information as the basis for recommendations and regulations on health and safety. To carry out independent large-scale preplanned research on worker health and safety (i.e., industrywide studies), the OSH Act gave NIOSH right of entry into private workplaces and ensured time and space for examination and interview of workers.

In place of various state-specific activities that previously had led to disparities in worker protection and health, the OSH Act standardized the establishment of regulations and periodic inspection of workplaces across the United States. The Act also established a rational system to generate and apply new knowledge relevant to worker safety and health. The OSH Act led to establishment of OSHA (a regulatory body) and, in April 1971, NIOSH (a research institute). NIOSH was envisioned as a science-based center dedicated to preventing occupational disease and injury. It was to have many interrelated functions that together would serve as a system for the scientific advancement of prevention.

Early on, epidemiology was deemed central to the work of NIOSH, and it played three major roles. The role most familiar to the rest of CDC, where NIOSH is located, is field epidemiology. At the request of workers, their labor representative, management, or state health departments, NIOSH (under the HHE program) conducts field epidemiologic investigations of individual workplaces. The field teams can consist of an epidemiologist, who often is a physician, and industrial hygienists, who are highly skilled in identifying potential workplace hazards, measuring and controlling levels of exposure, and identifying appropriate control strategies.

A second role for epidemiology is the conduct of large studies, often involving multiple industrial facilities across the United States, to assess the relationship of exposure and possible adverse outcomes. Epidemiologic associations sometimes are postulated by laboratory research in toxicology (also a forte of NIOSH) and sometimes by the astute observations of workers and their health-care providers. These large multiplant studies also assess the shape of the exposure–response relationship. Understanding the exposure–response relationship is essential to assessing risk, which is essential to recommending a level of exposure at which workers will not suffer short-term or long-term illnesses as a consequence of their work (e.g., the risk for lung cancer from exposure to diesel exhaust in the trucking industry [*4*]). Such large-scale studies are not limited to chemical exposure but include the evaluation of best practices for preventing injuries, such as slips, trips, and falls in hospitals (*5*) and other hazards.

The third role for epidemiology in NIOSH's work is surveillance for occupational disease and injury. The goals of this surveillance are to estimate the magnitude and trends of occupational disease and injury, identify new occupational diseases and injuries, detect sentinel health events that signal failures of prevention, and develop strategies for targeting all-too-scarce preventive resources to industries, occupations, and locations most in need.

Occupational disease surveillance is not new. It is rooted in the astute observations of Bernardino Ramazzinni (1663–1714) (*6*) about the relationship of occupation and disease in the 17th century, and of Alice Hamilton, a field epidemiologist and physician (*7*), who negotiated access to myriad industries and occupations during World War I and later, was intent on preventing occupational disease and injury.

Occupational health exists at the border between labor and management, and government support for preventing occupational injury and disease has waxed and waned with waves of political change (*1*). Renewed interest is often generated by fresh societal concern after occupational disasters with large numbers of victims, such as the Triangle Shirtwaist Fire of 1911 and the Farmington Coal Mine Disaster of 1968. This *MMWR* report provides examples of how NIOSH uses epidemiology to conduct field investigations in response to requests, to carry out large-scale investigations to assess causal associations or dose response relationships, and to maintain surveillance systems for occupational health and disease.

Field Studies in Response to Requests

Example: Bronchiolitis Obliterans in Workers at a Microwave-Popcorn Plant

In 2002, Kathleen Kreiss, a NIOSH scientist and former CDC Epidemic Intelligence Service (EIS) Officer, and colleagues reported an outbreak of bronchiolitis obliterans in workers at a microwave-popcorn production plant that used diacetyl as a butter flavoring agent (*8*). In response to a request from the Missouri Department of Health, which had received reports of eight former workers from the plant who became ill during 1993–2000, NIOSH conducted an epidemiologic field investigation and exposure assessment. In 2000, 117 current workers completing a symptom questionnaire had 2.6 times the expected rate of respiratory symptoms, twice the rate of physician-diagnosed asthma and bronchitis, and 3.3 times the rate of airways obstruction (10.8 times the rate for nonsmokers). Detailed assessment of exposures in the plant showed a strong relationship between exposure to diacetyl and current respiratory disease. As an example of the potential severity of the disease, according to NIOSH's investigation, one patient was a 40-year-old nonsmoking housewife who had begun work on the packaging line in 1993 and had become symptomatic with airway disease in 1994. At that time, her forced expiratory volume was only 24% of normal, and in 1995, she had been placed on a waiting list for lung transplant.

The prologue to the NIOSH investigation is instructive. During 1993–1998, several plant workers were seen by two pulmonary physicians in southwestern Missouri (*9*). The physicians found fixed airway obstruction and viewed the patients as atypical in that they worked in the same plant, smoked minimally or not at all, and did not respond to asthma medications. The pulmonologists referred the patients separately to national referral centers and expressed concern in one of their referral letters about similar cases associated with the same plant. They wrote that they had reported the situation to OSHA; OSHA inspectors had "visited the plant but concluded no lung hazards existed" (*9*).

Meanwhile, the spouse of one worker identified four additional coworkers who were similarly affected. That information was referred to a lawyer specializing in workers' compensation, who consulted an occupational physician, who in turn contacted the Missouri Department of Health. Subsequently, an experienced environmental health worker called CDC, which referred the call to NIOSH. A call from the NIOSH investigator to the Missouri state epidemiologist led to a request to NIOSH for assistance in a joint investigation. After completing the investigation, NIOSH continued to contribute to the understanding of this outbreak by conducting epidemiologic investigations at other similar plants, by conducting toxicologic studies, and by recommending regulatory and engineering solutions.

Overview

The Institute of Medicine (IOM) assessed the impact of field investigations conducted in response to requests from representatives of workers or industry (*10*). It described nine examples of hazards identified during 1978–2006 that resulted in "wide impacts." One was the example of diacetyl in the microwave-popcorn plant. In another example, exposure to dibromochloropropane (a nematocide previously associated with sterility in chemical production workers) was assessed among agricultural workers in several investigations during 1977–1981. OSHA used the findings to set a standard in 1979 limiting occupational exposure. In addition, IOM noted that a large number (337) of NIOSH investigations of lead exposure during 1978–1995 "provided information about exposures and control measures, consultation, and enforcement activities." IOM also noted 1) four investigations of silica exposure in the roofing industry that were cited as the basis for a curriculum designed to train 20,000 roofers to prevent occupational lung disease; 2) two investigations of finely ground silica, known as silica flour, that led to recommendations and regulations for control of occupational exposure; 3) eight investigations of flock made of synthetic fiber that was found to cause interstitial pneumonitis; 4) numerous investigations of musculoskeletal disorders that have informed OSHA and "stimulated major research activities within and outside NIOSH"; and 5) numerous field investigations by NIOSH demonstrating that powdered latex gloves were a risk factor for latex allergy, which played a role in replacing them with powder-free latex gloves.

Preplanned Large-Scale Studies

One of the major responsibilities assigned to NIOSH in the OSH Act is the conduct of epidemiologic studies of chronic and low-level exposure to chemicals in industry (i.e., industrywide studies). These studies are designed to detect an increased risk if it truly exists while avoiding a false negative finding resulting from small sample sizes or previously established exposure controls. Because many chronic diseases demonstrate latency between exposure and disease onset, the population studied must have sufficient years of exposure and sufficient years of follow-up to demonstrate a possible effect. To demonstrate an exposure–response relationship, which is critical to assessing causality and in establishing a level of exposure at which there is no effect, exposure must vary among cohort members.

Example: Studies of Mortality from TCDD

During the late 1970s and early 1980s, a confluence of interests led NIOSH to conduct a cohort mortality study of workers exposed to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD), one of many dioxin congeners. Studies from Scandinavia were pointing to an association among chemical production workers between TCDD exposure and excess risk for soft tissue sarcoma and lymphoma. Concern existed for veterans and others exposed during the Vietnam War to TCDD, an inadvertent contaminant of the widely used defoliant Agent Orange. Toxicologic studies were also pointing to an increased risk and a physiologic mechanism for toxicity, the aryl-hydrocarbon receptor. In 1980, the U.S. Department of Defense requested assistance from NIOSH in conducting an epidemiologic study of soldiers who had served in Vietnam. A recent EIS Officer (W.H.) and the Director of NIOSH, Tony Robbins, visited the Pentagon, where they learned of the limited available records that could be used to accurately characterize the location of soldiers in Vietnam and their exposure to defoliants. They concluded that a study in civilian exposed workers was more likely to be useful than a study among soldiers. The civilian study could then be applied to Vietnam War veterans.

In 1981, NIOSH began efforts to identify plants in the United States that produced chemicals contaminated with TCDD (*11*). In all, 5,172 workers at 12 plants were included in a cohort mortality study. An extensive effort was made to characterize workers' potential exposure to TCDD at these plants from job assignment records. TCDD was measured in serum from a subset of 253 workers. Cause of death on a death certificate was used as the outcome of interest. Vital status was ascertained as of the last day of 1987. The duration of exposure of the cohort members varied: 54% had <1 year of exposure; 29% had 1–5 years; 13% had 5–15 years; and 4% had ≥15 years. The latency from first exposure was substantial: >20 years for 61%. The analysis of all workers did not substantiate an excess risk for lymphoma but found a nonsignificant increase in soft tissue sarcomas. The analysis of workers with >1 year of exposure and 20 years of latency indicated a significant increase in death from lung cancer and soft tissue sarcoma, and an analysis of all cancers combined also showed a significant increase. In an updated analysis that extended determination of vital status and cause of death through 1993 (*12*), excess mortality from all cancers was still in excess—a 60% increase for workers in the highest exposure group. Estimated exposure for this group was 100–1,000 times higher than for the general population and similar to doses used in experimental animal studies that showed cancer excess. The original study (*11*) has been cited >400 times and the later study (*12*) 175 times. Both studies have been used in risk assessments of national and international importance, in decisions on compensation of veterans, and for other reasons.

Overview

Only one study—unpublished—has attempted to systematically evaluate the impact of NIOSH's large-scale epidemiologic studies (Mary K Schubauer-Berigan. NIOSH, personal communication, 2009). The International Agency for Research on Cancer has determined that 108 of 900 candidate agents were known human carcinogens. Schubauer-Berigan reviewed the literature cited by the International Agency for Research on Cancer for each occupational metal and fiber to identify the studies conducted by NIOSH. For epidemiologic studies, the results were as follows: chromium: three (8%) of 38 studies were conducted by NIOSH; cadmium: four (13%) of 30; crystalline silica: seven (28%) of 25; asbestos: 15 (9%) of 160; beryllium: all of eight.

The spectrum of diseases that NIOSH has studied is broad. Although a systematic census of studies is not available, examples include studies of cancer of various anatomic sites, cardiovascular disease, neurotoxicity, reproductive disorders, infectious diseases, and dermatitis. Many of these studies have been used in part as the basis for risk assessments and standard setting—for example dioxin, radon, beryllium, silica, and ethylene oxide and diesel exhaust. Another major focus of NIOSH studies has been respiratory disease, including those arising from the mining of coal, uranium, hard rock, cotton dust, vermiculite, and fibers. Traumatic injury, a major cause of occupational mortality and morbidity, also has been a major focus; such injuries include falls, electrocutions, amputations and violence. Industrywide studies also have focused on occupational sectors, such as construction, agriculture, and child labor.

Surveillance

Surveillance for NIOSH, as for the rest of CDC, follows a modified version of the definition established by Alexander D. Langmuir, the first chief epidemiologist of CDC: for NIOSH it is the systematic collection, analysis, and dissemination of health-related information for the purposes of prevention or control of disease or injury (*13*). NIOSH emphasizes that occupational surveillance information extends beyond mortality and morbidity to information about injuries, hazards, and exposures.

NIOSH surveillance studies developed in the 1970s and 80s under the guidance of Todd Frazier. Frazier and a former colleague from earlier days at Harvard, David Rutstein, and other NIOSH epidemiologists developed the concept of the Sentinel Health Event (occupation) or SHE(O) (*14*). A SHE(O) is "a

disease, disability, or untimely death, which is occupationally related and whose occurrence may: provide the impetus for epidemiologic or industrial hygiene studies; or serve as a warning signal that materials substitution, engineering control, personal protection, or medical care may be required." The SHE(O) list in 1983 comprised 50 conditions linked to occupational exposure. Rutstein coincidentally was a classmate in residency with Langmuir at Boston City Hospital, and both were employed after residency in an epidemiology training program in New York state. The concept of the SHE(O) led directly to an invigorated effort to involve selected state health departments in occupational disease and injury surveillance and investigation, the Sentinel Event Notification System for Occupational Risk (SENSOR) Program, which focused on the surveillance of selected persistent occupational diseases such as silicosis and lead poisoning. SENSOR was championed by Edward Baker upon his return to NIOSH in 1987 as Deputy Director.

NIOSH also established programs for state-based surveillance for occupational injuries, called the Fatality Assessment and Control Evaluation (FACE), which completed 2,202 investigations in seven targeted topic areas of concern, including electrocutions, confined spaces, falls from elevations, machinery, child labor, migrant agricultural worker conditions, and roadway work zones. NIOSH also created the National Traumatic Occupational Fatality (NTOF) Surveillance System, a national surveillance system that has provided comprehensive national data used to target research and prevention efforts, monitor trends, and identify previously unrecognized risks for occupational trauma. For example, during the 1980s, NTOF recognized occupational homicides as a leading cause of death, accounting for 13% of work-related traumatic deaths (*15*).

Example: Lead Poisoning in Adults

In 1983, Paul Seligman was assigned to NIOSH as an EIS officer. To satisfy a training requirement, he evaluated the potential of the Ohio workers' compensation system as a source of information to track the Healthy People 1990 objective to eliminate occupational lead poisoning (*16*). At that time, the incidence of occupational lead poisoning was unknown. Seligman was concerned that state-based surveillance that relied on physician reporting led to a woefully undercounted incidence of lead poisoning in adults. Around this time, evidence was increasing that lower levels of lead exposure in young children resulted in cognitive and neurobehavioral effects. As a result, CDC, the Council of State and Territorial Epidemiologists (CSTE), and Association of State and Territorial Health Officials had pushed to institute or amend state childhood lead poisoning reporting laws nationwide that required reporting of elevated blood lead levels (BLLs) in children to the state health departments.

Seligman recalls one of those vibrant moments of profound insight when he realized that, since all testing for blood lead in adults had to be done in one of just 70 OSHA-certified laboratories, using laboratory reporting as the foundation of surveillance for occupational lead poisoning was very feasible. Whereas most states focused on childhood lead poisoning, by 1981, four states (California, New Jersey, New York, and Texas) had required that all laboratories performing blood lead assays must report all elevated BLLs in children and adults to the state health department. In 1986, Seligman worked with these four states to publish an article in *MMWR* analyzing the states' data on elevated BLLs in adults, the vast majority of which came from workplace exposures.

To get states to expand their lead reporting requirements to include adults, Seligman worked with Henry Falk of CDC's National Center for Environmental Health to get the issue of adult lead surveillance on the agenda at meetings of CSTE and the Association of State and Territorial Health Officials. Armed with data from the four states and the support of articulate and persuasive allies in Linda Rudolph (California), Alice Stark (New York), Dennis Perotta (Texas), and Martha Stanbury (New Jersey), Seligman and Falk made a strong case for expanding the reporting of elevated BLLs to include everyone, not just children. In 1987, NIOSH and CSTE chose state-based lead poisoning surveillance as the first SENSOR condition for surveillance by using Seligman's idea for laboratory-based reporting. The system was called the Adult Blood Lead Epidemiology and Surveillance (ABLES).

NIOSH supported states using ABLES through cooperative agreements and required reporting of data by laboratories and health-care providers for adults with elevated BLLs. Supplementary data were subsequently gathered through interviews of workers, employers, and physicians. ABLES spread to 18 states by 1992, and is now active in 40 states. With the advent of ABLES, for the first time, data became available on the incidence, trends, and distribution of occupational lead poisoning. ABLES allowed estimates of the magnitude of lead poisoning and its distribution and trends over time and helped to identify high-risk industries, occupations, and specific workplaces in need of control measures. For example, ABLES reported a total of 9,871 cases of occupational lead poisoning for 2007(*17*), a decline from 14 per 100,000 employed adults in 1994 to 7.8 in 2007. Among the 40 participating states, prevalence rates ranged from 0.8 to 36.4 per 100,000 in the general population. Exposure at work accounted for about 80% of cases in adults. Industries with high rates included manufacturing of storage batteries and mining. Nonoccupational exposure accounted for about 5% of prevalent cases. NIOSH

and participating states were able to accomplish cooperatively all the goals of occupational disease and injury surveillance: estimating the magnitude and trend of disease, describing its distribution, identifying risk factors, and systematically collecting information useful for informing and providing preventive measures at specific worksites.

Overview

By working with states and other federal agencies, NIOSH has helped create an effective patchwork quilt of surveillance systems for the prevention of occupational disease and injury. State-based surveillance conducted in 23 states in cooperation with NIOSH as part of SENSOR now report statistics on 19 occupational health indicators, such as burns, amputations, and pneumoconiosis. Some states also conduct in-depth surveillance on silicosis, pesticide poisoning, occupational asthma, musculoskeletal disorders, sharps injuries in hospital workers, injuries among truckers, and fatal injuries among adults and teens. Surveillance for other conditions is conducted by NIOSH itself, including cardiovascular disease deaths and traumatic injury among firefighters, radiographic evidence of coal workers' pneumoconiosis, death from various pneumoconioses and malignant mesothelioma. NIOSH also collaborates with the Consumer Product Safety Commission in surveillance for occupational injuries in a sample of U.S. hospitals reported in the National Electronic Injury Surveillance System.

The Future

In 40 years, NIOSH has developed an extraordinary capacity to carry out 1) field studies in response to requests—in the tradition of shoe-leather epidemiology 2) large-scale multisite epidemiologic studies to understand more subtle causal relationships and establish dose–response relationships essential for assessing risk and recommending safe limits on exposure; and 3) surveillance for occupational diseases and injuries of national interest. Tribute for this accomplishment goes to the scores of epidemiologists whose careers have been spent in these efforts, to the leaders of NIOSH and CDC through the decades who understood that effective prevention of occupational disease and injury needs strong epidemiologic capacity in NIOSH, to Executive Branch and Congressional leaders who facilitated these efforts, and to progressive leaders of organized labor and industry.

Major challenges remain in epidemiology's contribution to preventing occupational disease and injury. One challenge is how to ensure the safety of new advances in commerce. For example, NIOSH is playing a leadership role in innovating an epidemiologic strategy for the advances in nanotechnology. Such anticipatory planning has not always been done in the past before the widespread adoption of new industrial technologies. For example, if the dangers of asbestos had been recognized before it was widely used, many major health consequences could have been avoided. Today, the early use of epidemiologic investigations can help reduce uncertainty about risks for occupational diseases and injuries as new industrial methods advance, even when adverse consequences of new technologies prove unfounded (e.g., early speculation about the possibility of cataracts or spontaneous abortion after using video display terminals).

A second challenge relates to NIOSH's role within the larger framework of prevention of occupational disease and injury in the United States. In contrast to the U.S. system for preventing infectious diseases, in which CDC's state partners have substantial resources, states have only marginal resources in the occupational health arena. Through a century of NIOSH and its predecessors, the federal government has been key to providing resources to enable states to develop capacity for occupational health and safety (L.P. Snyder. *The National Institute for Occupation Safety and Health, 1971–1996: a brief history*. Office of the Public Health Service Historian, 1997, unpublished data).

A third challenge is development and distribution of expertise. To understand this challenge, one can go back to Langmuir's original conceptualization of the EIS. One goal was enhancement of federal epidemiologic expertise. Another was to salt academic and health-care centers across the country with EIS graduates who would enhance disease prevention locally through the use of epidemiology. To be effective nationally in preventing occupational injury and disease, NIOSH must continue to be able to support a system for training experts, who will migrate to schools of medicine and public health and state and local health departments and who will train others. In addition, to sustain trainers, a robust support system is needed to sustain careers outside of NIOSH.

A fourth major challenge is expressed in a fundamental principle espoused by former CDC Director William Foege—that the world is a lifeboat inhabited by all peoples of all nations. With globalization, many industries and their inherent hazards to workers have moved overseas, often to countries where occupational safety and health are not considered important. Increasingly, the United States is accepting a role in ensuring that imported products are made to be safe, not just for U.S. consumer, but also for the workers who manufacture them overseas. One method to ensure health and safety is by developing international training programs, particularly in occupational epidemiology and industrial hygiene.

The ultimate challenge for NIOSH is to not only effectively control occupational diseases and injuries that are the

remnants of the last century, but also to preempt new hazardous exposures and conditions from gaining a foothold in the new century.

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Trends in Global Health and CDC's International Role, 1961–2011

Kevin M. De Cock, MD
Center for Global Health, CDC, Atlanta, Georgia

Corresponding author: Kevin M. De Cock, MD, Center for Global Health, CDC, MS D69, 1600 Clifton Road, N.E., Atlanta GA 30329-4018; Telephone 404-639-0119; Fax: 404-639-7490; E-mail: kmd2@cdc.gov.

Introduction

In late August 2007, Dr. Peter Kilmarx, a CDC epidemiologist working on HIV/AIDS, awoke at his home in Atlanta to read a text message on his mobile phone. The message, sent the night before, was from Gilbert Shamba Mayi, the chief of Bakawa Tombe, a small village in Kasai Occidental Province in the Democratic Republic of Congo. Dr. Kilmarx had met the chief approximately 20 years earlier while serving in the Peace Corps. The message said in a local Congolese language, "Bakwa Tombe greets you with pleasure. There is a lot of death from Ebola. When are you coming for the hospital? How are you Peter? Chief Gilbert Shamba Mayi."

This real time text message from a "citizen epidemiologist" in a remote Congolese village led to deployment of a CDC team to the affected area in less than 2 weeks, and they determined quickly that the cause of the outbreak was Ebola hemorrhagic fever. Compare this anecdote to an experience of the author of this article, Dr. Kevin DeCock, while he was an Epidemic Intelligence Service Officer 21 years earlier in 1986. A severe outbreak of yellow fever started in Benue State, Nigeria, during the middle of 1986 and had already peaked by the time it came to national attention in October of that year. An outbreak investigation by an international team began in December. By the time the international team arrived, approximately 40,000 yellow fever infections and 5,000 deaths had already occurred (*1*).

The contrast between these two anecdotes vividly shows how technological change has affected the way CDC and other U.S. agencies do their global work. Large-scale social and technologic changes have wrought changes in international public health practice and these changes will continue, or even speed up, in the future.

One example of these changes is a recent increase in the level of priority accorded to international activities at CDC. Shortly after assuming his role as Director of CDC in 2009, Dr. Thomas Frieden identified five priorities for the agency. One of them was to increase CDC's impact in global health. To support this objective, he created the Center for Global Health, reflecting the increased importance of global health in general, the relevance of global health to health in the United States, and the increased international role of CDC. In this same vein, the U.S. Department of State recently released *The First Quadrennial Diplomacy and Development Review: Leading through Civilian Power* (*2*), which emphasized the increased international importance of different civilian agencies whose traditional mandates have primarily been domestic.

As *MMWR* celebrates its 50th year at CDC, a review of *MMWR* articles provides evidence that CDC's global activities have become firmly established as part of the agency's core work. Electronic searching of *MMWR* articles for the words "international" or "global" found only five articles mentioning them in 1983, compared with 130 articles in 2010. CDC responded to five international requests for epidemiologic assistance ("Epi-Aids") before *MMWR* came to CDC in 1961 and to 534 such requests through January 2011.

Evolution of Global Health: Tropical to International to Global

The term *global health* has replaced such earlier names as *international health* and *tropical medicine*. These labels reflect the evolution in scale and scope of the subject and of the work of diverse agencies, including CDC, since the 1960s and of their broader mission and activities. The concept of global health has evolved during the past 50 years from a narrow view of ecologically and geographically restricted health challenges to a broad and comprehensive approach to health in the world as a whole.

Tropical medicine developed in the late 19th and early 20th centuries, an era when many countries of the Southern Hemisphere were colonized by countries of the Northern Hemisphere. It focused on diseases associated with warm climates, many of which were parasitic (e.g., malaria, sleeping sickness, and schistosomiasis). Together with epidemic-prone viral or bacterial diseases, such as yellow fever, typhoid, and dysentery, these tropical diseases were recognized early on as common causes of death and major threats to public health. To prevent and treat these diseases, training in tropical medicine became a priority for institutes preparing northern professionals for overseas service.

The term *international health* became widely used after colonial independence and was accompanied by a change in focus toward aid and humanitarian assistance to countries of the developing world. Infectious and parasitic diseases, maternal and child health, and nutrition were the most common components of these early international health efforts.

Global health now encompasses tropical medicine and international health but extends beyond them in diverse ways (*3*). It broadens the agenda internationally and considers health at the global level. For example, it includes strengthening and supporting systems required to implement health interventions and mechanisms for coordination of public health activities. It includes health education and prevention and extends to oversight of clinical services appropriate for the local impact of disease. Global health recognizes the reality of globalization and prioritizes public health challenges that transcend individual country boundaries and require collective action, such as threats from infectious agents like HIV, but also from environmental and climate change; rapid and widespread urbanization; and changes in socioeconomic conditions, diet, and lifestyles. Global health is guided by epidemiologic science and research and has as core values concepts of justice, decency, human rights, and health equity. It also recognizes the overwhelming relevance and importance of policy, politics, and diplomacy.

Trends in Global Health, 1961–2011

Advances in global health and science since *MMWR* was established at CDC have been extraordinary (Table 1). Two infectious agents, smallpox in humans and rinderpest in cattle, have been eradicated. Enormous progress has been achieved toward the eradication of poliomyelitis and dracunculiasis (i.e., guinea worm disease). Polio remains endemic in only four countries (India, Nigeria, Afghanistan, and Pakistan), and cases in 2010 were at an all-time low: 1,292 total (232 in countries where polio is endemic and 1,060 in countries where polio is not endemic) (*4*). Reports of guinea worm disease in 2010 were lower than ever before (<2,000), from only five remaining affected countries (Chad, Ethiopia, Ghana, Mali, and Sudan).

A host of new or drug-resistant pathogens and associated diseases have been described, with resulting outbreaks of varying severity and distribution that emphasize the necessity for public health preparedness. The most acutely lethal have been the hemorrhagic fevers caused by such agents as Lassa, Marburg, and Ebola viruses, but certain sexually transmitted (HIV) and airborne-transmitted (severe acute respiratory syndrome [SARS], multidrug- and extensively drug-resistant tuberculosis [TB]) agents have had greater public health impact.

A large number of policy initiatives were launched, new bodies established, influential reports published, and philanthropic foundations created, all contributing to a fundamental realignment of global health architecture and governance. At the start of the 21st century, the global community committed to the Millennium Development Goals (MDGs), of which three were specifically devoted to health (MDGs 4, 5, and 6, relating, respectively, to child health; maternal health; and HIV, TB, and malaria).

Other MDGs focusing on economic development have considerable implications for health, most directly MDG 7 relating to environmental sustainability. Progress has been made toward reducing the proportion of persons without access to safe drinking water, currently almost one billion people, but little progress has been made in increasing access to sanitation. In 2008, 69% and 64% of the population of southern Asia and sub-Saharan Africa, respectively, lacked access to basic sanitation (*5*). Forty-four percent and 27% of persons in these regions, respectively—approximately 1.1 billion persons—had to resort to open defecation, an affront to human dignity (*5*). That settings exist today where humans have greater access to mobile phones than to toilets reflects unfavorably on globalization.

The World Health Organization (WHO) embraced the goal of malaria eradication in 1955, but this ambitious aspiration was abandoned in the late 1960s in the face of technical and social challenges. During the past few years, the President's Malaria Initiative, the Global Fund to Fight AIDS, Tuberculosis, and Malaria, and other donors have begun to address the estimated 225 million cases of malaria and almost 781,000 deaths annually (2009 estimates) (*6*). The focus has been on delivering artemesinin-based combination therapies, better diagnostics, insecticide-treated bednets, indoor residual spraying, and interventions for malaria in pregnancy to millions of persons at risk.

As its name suggests, the Global Fund to Fight AIDS, Tuberculosis, and Malaria was developed to address these three diseases that have so disproportionately affected global health, particularly in sub-Saharan Africa. In addition, the President's Emergency Plan for AIDS Relief (PEPFAR), the largest bilateral health program ever mounted, has contributed an unprecedented U.S.$32 billion thus far to the fight against HIV/AIDS, including against HIV-associated TB (*7*). Currently, approximately 5.2 million HIV-infected persons in low- and middle-income countries are accessing antiretroviral therapy compared with <400,000 in 2003 (*8*). Despite remaining the leading infectious disease challenge in global health, the HIV/AIDS epidemic has stabilized, and investments in addressing it are beginning to pay visible dividends in other spheres of health.

TABLE 1. Selected achievements and milestones in global health, 1952–2011

Year	Event
1952–1965	Global Yaws Control program, jointly sponsored by WHO and UNICEF, reduces yaws prevalence by 95%.
1962	CDC becomes involved in smallpox eradication program (http://www.cdc.gov/about/history/timeline.htm).
1961, 1962, 1963	Oral polio vaccine licensed in the United States.
1964	First US Surgeon General's report on tobacco and health published.
1965	First report on diabetes issued by WHO.
1967	First heart transplant performed by Christiaan Barnard in South Africa.
1969	International Health Regulations (cholera, plague, smallpox, yellow fever) launched by WHO.
1970–2002	World child mortality rate down approximately 45% (2003 World Health Report).
1970–2010	World child mortality rate declines approximately 52%.
1974	Onchocerciasis (river blindness) initiative launched in western Africa by WHO, the World Bank, the UN Development Program, and the Food and Agriculture Organization; 18 million children spared disease; 600,000 cases of blindness averted.
1976	Ebola virus first identified in Sudan and Zaire (now Democratic Republic of Congo).
1976	Legionnaires disease recognized.
1977	Essential Medicines List developed; 156 countries today maintain list.
1978	The Alma-Ata Declaration of 1978 issued at the International Conference on Primary Healthcare convened by WHO. The declaration became a major milestone in the field of public health. It identified primary health care as a critical element to achieve.
1979	Smallpox eradication declared.
1980	Combating Communicable Diseases Program developed by US Agency for International Development.
1981	First case descriptions of what would become known as AIDS published in *MMWR*.
1983	HIV identified by coworkers from Institut Pasteur, leading to Nobel Prize in Physiology or Medicine in 2008.
1984	Projet SIDA established in Zaire (now Democratic Republic of Congo).
1984	Bhopal, India, environmental disaster occurs.
1985	Inaugural CDC Field Epidemiology Training Program (later Field Epidemiology and Laboratory Training Program) launched in Thailand.
1986	Chernobyl, USSR (Ukraine), environmental disaster occurs.
1986	WHO's first program on HIV/AIDS established.
1988	Global Polio Eradication Initiative launched as a result of a resolution passed by the World Health Assembly in 1988 calling for the eradication of polio by 2000.
1993	World Bank World Development Report, *Investing in Health*, published.
1994	Polio elimination certified in the Americas.
1995	Directly Observed Therapy–Short Course program for tuberculosis management launched by WHO.
1995	International Commission for Dracunculiasis (guinea worm disease) established.
1995	Joint UN Global Programme on HIV/AIDS established.
1996	"Final rule" on folic acid flour fortification published by US Food and Drug Administration.
1996	Combination antiretroviral therapy highlighted at International Conference on AIDS in Vancouver, British Columbia, Canada.
1997	Highly pathogenic H5N1 first described in humans (infected through contact with infected birds) in Hong Kong.
1998	Global Youth Tobacco Survey (WHO–CDC initiative) established.
2000	UN General Assembly Special Session on HIV/AIDS held.
2000	Millennium Development Goals set by the UN as part of the UN Millennium Declaration in 2000.
2000	Bill and Melinda Gates Foundation established.
2000	International Conference on AIDS held in Durban, South Africa, to highlight AIDS in Africa.
2001	Measles control initiative launched jointly by the American Red Cross, UN Foundation, CDC, UNICEF and WHO.
2001	WHO Global Strategy for Containment of Antimicrobial Resistance established.
2002	Global Fund established.
2003	SARS erupts and is controlled.
2003	US President's Emergency Plan for AIDS Relief announced.
2003	Joint UN Global Programme on HIV/AIDS/WHO "3 by 5" initiative launched to provide ART to 3 million persons with HIV/AIDS in low- and middle-income countries by the end of 2005.
2005	International Health Regulations revised.
2005	Partnership for Maternal, Newborn and Child Health created through the collaboration of the Partnership for Safe Motherhood and Newborn Health (WHO); the Healthy Newborn Partnership (Save the Children USA); and the Child Survival Partnership (UNICEF).
2005	US President's Malaria Initiative established.
2005–2010	HIV/AIDS progress reported. Widespread availability of ART and prenatal interventions reduce vertical transmission; male circumcision demonstrated to reduce transmission; access to HIV testing and counseling improved; novel research into preventatives; (e.g., vaginal gel antiretroviral pills).
2008	WHO report on strengthening of health systems, *Everybody's Business*, released.
2008	Report on the Social Determinants of Health issued by WHO.
2009	Global Health Initiative announced by US President Obama
2009	Earthquake in Haiti and subsequent cholera epidemic occur.
2010	Severe lead poisoning outbreak occurs in Zamfara State, Nigeria.
2010	Meningitis vaccine launched in "meningitis belt" (Burkina Faso).
2010	Global Polio Eradication Initiative Strategic Plan 2010–2012 released. CDC prepares first quarterly risk assessment for Independent Monitoring Board, which conducts first review of progress toward meeting Global Polio Eradication Initiative milestones.

Abbreviations: WHO = World Health Organization; UNICEF = United Nations Children's Fund; UN = United Nations; SARS = severe acute respiratory syndrome; ART = antiretroviral therapy.

Important demographic changes during the past 50 years have resulted from changing trends in child, maternal, and adult death rates. These rates reflect changing patterns of disease secondary to economic development and specific public health interventions. Child and maternal death rates have been the most important and widely used indicators of health in different countries. In 2008, 7.95–8.8 million deaths occurred among children <5 years of age, compared with 11.9 million deaths in 1990 and approximately 16 million deaths in 1970 (*9*). Thirty-three percent of these deaths occurred in southern Asia and 50% in sub-Saharan Africa, with the highest death rates for children aged <5 years found in western Africa.

Rates in all components of mortality in children aged <5 years (neonatal, postneonatal, and childhood) are declining, but unequally. Decline has been faster in rates of postneonatal and childhood mortality than neonatal mortality, most likely reflecting investment in preventive services, such as vaccination and malaria prevention, as well as better prevention and management of diarrheal diseases, respiratory infections, and HIV/AIDS. The reduction in global measles-related mortality, estimated at 78% during 2000–2008, has been especially striking. As a consequence of these trends, neonatal mortality, often associated with the same factors as maternal mortality (itself highest in sub-Saharan Africa and southern Asia), accounts for an increasing proportion of deaths in children aged <5 years. As many as 51% of deaths prevented in children <5 years might be attributable to increased education of reproductive-aged women (*10*).

MDG 5 calls for a 75% reduction in the global maternal mortality ratio from 1990 to 2015. Despite pessimism around this objective, which depends on access to clinical services that include emergency obstetric care, maternal deaths have decreased from an estimated 526,300 in 1990 to 342,900 in 2008 (*11*). The corresponding reduction in the maternal mortality ratio was from 320 to 251 per 100,000 live-born infants, suggesting that despite this improvement, MDG 5 was unlikely to be met by 2015. MDG 5 also called for universal access to services, such as family planning, in which progress has stalled.

The focus of the health-related MDGs on maternal and child health obscures major trends and underlying causes of adult mortality. However, preventable adult mortality has become a key indicator of health in many countries, reflecting the emerging pandemic of noncommunicable diseases and injuries. By 2010, two deaths occurred among adults aged 15–64 years for every death among children <5 years of age globally, and the ratio is even higher for adults <70 years of age: three deaths among adults to every one death among children (*12*). Despite marked regional variations and confounders, such as HIV/AIDS and its treatment, these trends toward an increasing ratio of deaths in adults apply worldwide, and they apply disproportionately to males.

These broad mortality trends do not reveal some of the major shocks that caused substantial disruption at the local or regional level. One example is HIV/AIDS, which has had devastating impact in eastern and, especially, southern Africa, causing massive loss of life expectancy. Global HIV incidence is considered to have peaked around 1996 and has declined since then (*9*). AIDS-related mortality most likely peaked in 2004. Another example is increased mortality in the former Soviet Union during the 1990s. This increase was caused by profound social and political change, and the resultant mortality was at the level usually associated with war and conflict in numerous low- and middle-income countries.

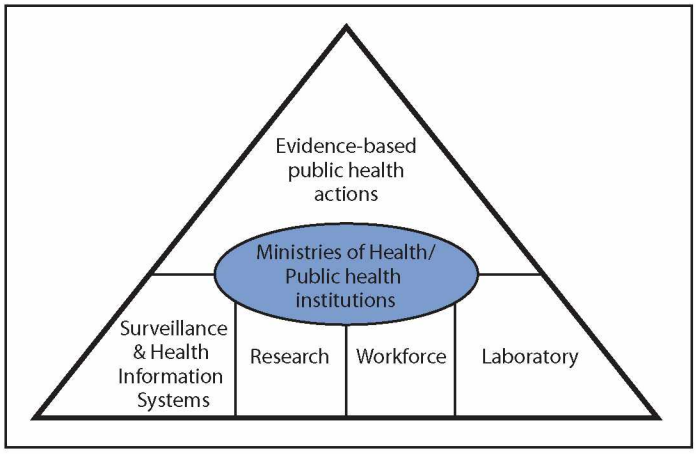
CDC's Role in Global Health

CDC's current global health activities build on the momentum developed through historical collaborations in the eradication of smallpox and continue as global partners strive to fulfill MDGs. CDC's programs are designed to achieve substantial and positive health outcomes through enhanced health security and strengthened health systems around the world. The agency's global work is characterized by evidence-based public health actions and extensive collaboration with in-country partners and international organizations. These partnerships address in-country needs in surveillance, research, workforce development, and laboratory capacity (Figure).

Partnerships are the cornerstones of CDC's global work. In addition to collaborating with sister agencies in the federal government, CDC's principal partners in global health are ministries of health (MOHs) and agencies of the United Nations, especially WHO and the United Nations Children's Fund (UNICEF). In addition, CDC works directly with specific in-country nongovernment organizations and health institutes. With CDC offices in 41 countries, and staff assigned to 51 countries, the agency provides technical assistance, mentoring, and emergency surge capacity directly to MOHs and through WHO to build national and regional capacity.

Examples of CDC's direct assistance to MOHs include the agency's HIV/AIDS programs and global disease-detection activities. CDC's Division of Global HIV/AIDS (formerly called the Global AIDS Program) provides direct, peer-to-peer, technical, financial, and program delivery assistance to MOHs. This assistance includes collaborations to build sustainable public health information, laboratory, and management systems. Multiagency work requires interdisciplinary

FIGURE. Public health framework for health systems strengthening at CDC



collaboration between clinicians, epidemiologists, health educators, and other scientists, an example of which is the "Basic Care Package." Developed by CDC in 2008, the package combines interventions (antibiotic medication, insecticide-treated bednets, services for screening and management of sexually transmitted infections, prevention of maternal-to-child transmission services, and a safe water tool) that have dramatically reduced illness and improved the quality of life for persons with HIV in Uganda, Ethiopia, Cote d'Ivoire, Kenya, Nigeria, Malawi, Rwanda, Uganda, Vietnam, and Zambia. Through PEPFAR, CDC and its global partners have provided care to >11 million persons affected by HIV/AIDS, including 3.8 million orphans and vulnerable children. More than 3.2 million persons are alive and 114,000 infants are HIV free because of this aid (*7*).

CDC also responds to MOH requests to assist with the identification and containment of infectious diseases and other health threats. Almost all of CDC's national centers have participated in rapid outbreak investigations, pathogen discovery, training, and networking. During the past decade, CDC has played a lead role investigating and responding to such global threats as pandemic influenza A (H1N1) 2009 and SARS. During 2010, CDC's Global Disease Detection program coordinated the response to 14 direct requests from MOHs for technical assistance related to health threats, including cholera in Haiti and the Dominican Republic, hepatitis E virus in Uganda, lead poisoning in Nigeria, meningitis in Ghana, nodding disease in Uganda and southern Sudan, and polio in the Democratic Republic of Congo.

CDC also partners extensively with multilateral global health organizations. WHO is a key collaborator. Currently, 29 CDC staff members are seconded to WHO headquarters and regional programs, providing expertise in areas such as HIV/AIDS, influenza, meningitis, measles, polio, immunization, sexually transmitted infections, and TB. These partnerships not only provide technical assistance from CDC to agency partners but also create opportunities for CDC to learn directly from communities in-country. For example, CDC staff are currently working as part of the Pan American Health Organization regional Global Water, Sanitation and Hygiene Program cluster in Haiti, learning how tools such as CDC's Safe Water System can be adapted for use in postearthquake Haiti.

Disease surveillance is the foundation for evidence-based public health action, and enhancing global surveillance systems is the foundation of CDC's global health programs. One of CDC's core global health missions is to share its expertise, raising the level of global health surveillance. The agency trains staff members from partner organizations in the process of collecting, analyzing, interpreting, and disseminating health-related data to better inform solutions globally. CDC and its partners use these data to determine potential interventions; monitor their impact; and determine at-risk populations, disease trends, and potential interventions.

In recent years, CDC has assisted in strengthening several surveillance efforts around the world. For example, CDC's surveillance role is highlighted in the President's Malaria Initiative. CDC advises the U.S. Malaria Coordinator on priorities for surveillance strategies and processes. In 2010, other examples of CDC's global surveillance work included hand, foot, and mouth disease and *Salmonella enterica* serovar Enteriditis in the People's Republic of China; human influenza A (H5N1) infection and Q fever in Egypt; dengue, respiratory syncytial virus, and febrile encephalitis in Guatemala; micronutrients and malnutrition in Jordan, Dominican Republic, and Uganda; and tobacco use among teens and adults in Latin America.

CDC also is involved in research that supports global public health action. The recently released WHO guidelines for TB screening and prevention in persons with HIV infection (*13*) illustrates how CDC's investment in science influences global health policy and improves health outcomes. Research conducted by CDC in Thailand, Cambodia, and Vietnam in collaboration with the U.S. Agency for International Development and other partners led to more accurate screening for TB so that TB can be diagnosed and treated earlier in persons with HIV infection (*13*). In another example, CDC collaborated with UNICEF and in-country partners to conduct research on the prevalence of sexual violence against women and girls in Swaziland. The study found that one in three respondents had experienced sexual violence before 18 years of age. The results led to critical policy and programmatic actions, including establishment of child-friendly courts and integration of Domestic Violence and Sexual Offenses units into 75% of police stations in Swaziland.

CDC enhances global public health capacity through in-country workforce development. For approximately 30 years, CDC has invested in developing the skills of the global public health workforce. Through its signature training program, the Field Epidemiology Training Program (FETP), CDC works with MOHs and other partners to train skilled epidemiologists worldwide. Its specialized laboratory track, Field Epidemiology and Laboratory Training Program (FELTP), provides training and support for enhanced in-country laboratory disease surveillance and outbreak response. Through FETP and FELTP, CDC has helped establish 35 self-sustaining programs that have produced approximately 2,100 graduates from 51 countries. The graduates have become leaders of MOHs, reducing dependence on foreign health assistance. Examples of this transition can be found in a recent response to Rift Valley fever in Kenya. In an outbreak during 1997–1998, CDC provided primary leadership for the investigation. In a subsequent outbreak during 2006–2007, primary leadership for the response was provided by staff in Kenya who had trained through the Kenya FELTP, which is implemented jointly with CDC and is now led by Kenyan graduates.

During the past 20 years, CDC also has invested in development of public health management and leadership capacity globally. Through CDC's Sustainable Management Development Program, CDC works with MOHs and other partners to strengthen managers' skills and competencies, improve program operations, and promote changes in policy and health systems.

CDC increases laboratory capacity and extends global laboratory systems. In addition to training laboratorians through FETLP, CDC works alongside its partners to build laboratory capacity and systems. For example, CDC is the founding member, and chairs the steering committee, of PulseNet International, an international network of seven national and regional laboratory networks dedicated to tracking foodborne infections worldwide. Currently, PulseNet is partnering with reference laboratories throughout the world to build capacity for molecular surveillance of foodborne infections. It has increased collaboration between international reference laboratories through the addition of 82 new member countries since 1996 and collaborated in the advancement of detection, investigation, and control methods of international outbreaks of foodborne infections.

After the devastating earthquake in Haiti on January 12, 2010, CDC deployed staff to rebuild Haiti's laboratory capacity. Haiti's national laboratory was one of the few public health structures in the nation's capital to survive the disaster, but it lacked key supplies and training to detect potential health threats likely to follow the earthquake. CDC and its partners quickly provided equipment, rapid diagnostic tests, and training to Haiti's laboratory technicians. Enhanced capacity has resulted in increased submissions of specimens to the national laboratory; an average of 181 bacteriologic tests are performed each month to confirm diagnoses of diseases ranging from leptospirosis to meningococcal meningitis. As a result of rapid laboratory strengthening in Haiti, the country's National Public Health Laboratory was able to identify cholera cases within days after the outbreak began.

Future Trends in Global Health

These three broad themes provide the framework for CDC's current work around the globe: enhancing public health capacity, increasing health security, and maximizing health impact from programs and interventions (Figure). CDC's future role will continue within this framework with a goal to create increasing in-country public health capacity and independence. CDC hopes to create an analogous relationship between CDC and its global partners that the agency currently has with its domestic state public health partners. CDC has seen its role with U.S. state health departments change from intense engagement initially to a consultative role where local capacity is well established. In a globalized environment, interactions between CDC and its MOH partners may increase, but the scope and intensity of CDC engagement in any country should change to consultation as national and local public health expertise develops. The development and strengthening of national public health institutes globally is a clear step in this direction (*14*) Country leadership is prioritized by CDC through all its global programs, including PEPFAR and the agency's leadership activities related to the Global Health Initiative.

Despite the unfulfilled commitments relating to the MDGs and infectious diseases, global health discourse and donor prioritization will be influenced by geopolitical and socioeconomic changes. Financial downturn and political changes in donor countries may tighten budgets for health programs for years to come. An emphasis on integration and systems models broadens and strengthens specific disease initiatives. Many countries are in positions to devote more resources to health than they have previously. Some middle-income countries have emerged as leaders in debates around such issues as intellectual property and health policy and could contribute more to global health financially than they currently do.

Discussion will continue about the relative roles and interaction of public health and development internationally. Both are necessary, and neither alone can guarantee sustained health or address all health challenges in a timely and comprehensive manner. Perhaps the most acute test of how well development

and public health collaborate and deliver results is the ongoing situation in Haiti as it recovers from the 2010 earthquake and cholera epidemic. Only time will determine whether Haiti emerges from these shocks a stronger and healthier society with better basic infrastructure, such as for water and sanitation.

The disproportionate effect of disease and early death in sub-Saharan Africa inevitably means that much attention of the global health community will focus on that subregion. Discussion is needed about how best to use resources, including the balance between addressing high rates of disease affecting small populations versus large populations with modest rates that have large numbers of persons affected because of the large denominator. UNICEF has recently prioritized its activities in terms of equity, arguing that disproportionate health impact is obtained from focusing interventions on the most marginalized and underprivileged communities (*15*). Certain countries (e.g., Nigeria, Democratic Republic of Congo, and Pakistan) contribute disproportionately to child and maternal mortality because of their large size and adverse health indicators and may merit particular attention.

In addition to finishing preexisting commitments to the MDGs, polio eradication, and other infectious disease priorities, several urgent needs stand out. The lack of mortality surveillance in many countries prevents recognition and description of the local impact of disease. The solution is the development of robust vital registration systems in every country, but until that is achievable, systems are needed to capture data on mortality through enhanced surveillance or surveys. Changing global trends in patterns of mortality means that the classic indicators most widely used (child and maternal mortality) fail to accurately describe the health situation—including the increasing proportions of deaths in young adults and the emerging impact of noncommunicable diseases and injuries—in many countries. Obtaining data on preventable adult mortality and its causes is a priority for surveillance systems globally.

To address some of the challenges and assess its own performance, CDC has identified five major public health goals for which major progress can be made with sustained, coordinated effort. These are 1) reduction of mother-to-child HIV transmission and congenital syphilis; 2) enhanced coverage and impact through global vaccination initiatives, including polio; 3) elimination of lymphatic filariasis in the Americas; 4) reduced tobacco use; and 5) decreased motor vehicle injuries. These "winnable battles" have been named as priorities for intervention because of the availability of practical, evidence-based strategies, and the potential for measuring progress across a large proportion of persons at greatest risk. The timelines and specific measurable objectives for CDC's global winnable battles are under development. Approaches to evaluating progress in these areas are under discussion, and priorities may change over time as new challenges or opportunities arise. These topics should not be interpreted as displacing CDC's broad global health portfolio, but they do represent areas for special focus. They will be implemented as part of CDC's comprehensive global health framework of increasing in-country public health capacity, health security, and health impact.

Despite predictions about global health trends, objectives set by the MDGs, and winnable battles, predicting what issues will preoccupy *MMWR* and global health 50 years from now is risky. Further progress should be expected in the development of diagnostics, including those used at the point of care; drugs; and vaccines. New diseases will continue to emerge; environmental and climate change may become more prominent risk factors for adverse outcomes; and the effect of noncommunicable diseases will continue to grow. Communications capacity can only continue to increase, and the story of Chief Gilbert Shamba Mayi will be less unusual.

Even as the environment changes certain constants will remain, including the need for reliable data for public health action, surveillance, laboratory capacity, a strong health workforce, and research. CDC will also have to evolve, yet remain true to the core values that have guided its work over the years, much of it described in *MMWR*.

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Advice to a Modern-Day Rip Van Winkle: Changes in State and Local Public Health Practice During the *MMWR* Era at CDC

Melvin A Kohn, MD[1]
David W Fleming, MD[2]
[1]*Public Health Division, Oregon Health Authority, Portland, Oregon*
[2]*King County Health Department, Seattle, Washington*

Corresponding author: Melvin A. Kohn, MD, 800 N.E. Oregon, Suite 930, Portland, OR 97232;Telephone: 971-673-1300; Fax 971-673-1361; E-mail: melvin.a.kohn@state.or.us.

Imagine for a moment a dedicated but exhausted state or local public health practitioner nodding off while reading the volume 10, number 1, issue of *MMWR* in January of 1961, only to awaken, a la Rip Van Winkle, 50 years later (*1*). What would be most surprising to our time-traveling colleague about state and local public health practice in 2011? Here is our top 10 list.

1. There are some "old" diseases about which you no longer have to worry much and some "new" ones you do.

Buy yourself an up-to-date infectious disease textbook. Vaccines have driven rates of many diseases that were common in 1961 to very low levels today in the United States. Polio, measles, invasive *Haemophilus influenzae* disease, and diphtheria are rarities, and smallpox has been eradicated (Table). In fact, it has become a challenge to get health practitioners to recognize these old diseases when they do occur and to mount a rapid, competent public health response to them unless a "senior" epidemiologist happens to be around. After your experiences with controlling polio in the United States during the 1950s, you might be amazed at the increasing problem of "vaccine hesitancy" (*2*). The rarity of many of the old diseases has made it difficult to convince a growing subset of parents to vaccinate their children against them.

TABLE. Cases of selected reportable diseases — United States, 1961* and 2008†

	Reported cases by year	
Disease	**1961**	**2008**
Poliovirus infection, all types	1,312	0
Measles	423,919	140
Invasive *Haemophilus influenzae*	19,500§	2,886
Diphtheria	617	0

* CDC. Annual supplement: reported incidence of notifiable diseases in the United States, 1961. MMWR 1962;10(53):1–28.
† CDC. Summary of notifiable diseases—United States, 2008. MMWR 2009; 57:19–20.
§ Invasive *Haemophilus influenzae* cases estimated for 1985, as reported in Bisgard KM, Kao A, Leake J et al. *Haemophilusinfluenzae* invasive disease in the United States, 1994–1995: near disappearance of a vaccine-preventable childhood disease. Emerg Infect Dis 1998;4:229.*Haemophilusinfluenzae* was not nationally notifiable before 1991.

On the treatment side, rates of tuberculosis (TB) have been driven to historic lows, and in many jurisdictionsTB expertise has all but disappeared. At the same time, drug treatment for TB and many other infectious diseases has become complicated by the continuing emergence of strains resistant to common treatments (*3*).

Read that new textbook carefully because many infectious diseases of importance today were unknown (or unrecognized) when you fell asleep in 1961. Legionnaires disease (*4*), toxic-shock syndrome (*5*), hantavirus pulmonary syndrome (*6*), Lyme disease (*7*), cryptosporidiosis (*8*), norovirus infection (*9*), and *Escherichia coli* O157:H7 infection (*10*) are a few examples. Most commonly, these new illnesses were identified as a result of outbreak investigations by CDC together with state health departments. A key to success at characterizing and controlling these new diseases has been an explosion of new laboratory techniques, such as pulsed-field gel electrophoresis and polymerase chain reaction (you may need a textbook on infectious disease laboratory testing as well), which have enabled more sensitive testing and more specific characterization of pathogens. The creation of national surveillance systems, such as PulseNet (*11*) (which allows comparison of the molecular "fingerprints" of foodborne pathogens from across the country), has helped in the detection of many more multistate outbreaks (and provided lots of practice on improving cross-jurisdictional and cross-agency coordination).

2. There is a global HIV pandemic.

The first five cases of what is now called acquired immunodeficiency syndrome (AIDS) were reported in *MMWR* in 1981 (*12*). Since then, human immunodeficiency virus (HIV, the virus that causes AIDS) has caused approximately 25 million deaths across the world, and in 2007 alone, 2.7 million new infections occurred (*13*), painfully showing the limits of traditional approaches to communicable disease control.

In 1961, control of sexually transmitted diseases focused primarily on providing health education, treatment, and contact tracing. For HIV, the lack of a cure and a vaccine has limited our ability to use these traditional tools. Moreover, traditional

health education and contact tracing is more complicated and less useful among persons at highest risk in this country—men who have sex with men and injection drug users (drug use became epidemic while you slept) (*14,15*). To implement effective harm-reduction strategies, public health and health-care professionals have needed to work closely with those at highest risk and to partner with leaders and community-based organizations from these socially marginalized communities.

This work has brought public health into the dangerous shoals of culture wars around sexuality, homosexuality, abstinence, drug use, and personal responsibility. Today, managing conflicts with politicians and mainstream cultural beliefs is now part of routine work. Especially at the beginning of the AIDS epidemic in the 1980s, the lack of empowerment and stigmatization of homosexuals, racial and ethnic minorities, and women were major contributors to the behaviors that fueled the spread of HIV (*16*), and the emergence of HIV has highlighted for many practitioners the link between public health and human rights.

By providing the dispassionate imprimatur of solid science for issues such as needle exchange (*17*) and HIV reporting systems (*18*), CDC and *MMWR* have helped practitioners maintain focus on disease prevention as the primary objective. But on many occasions, politics have prevailed over good science, teaching the limits of pure science-based public health practice.

3. Health care dominates the United States economy, but many public health agencies do not see many patients anymore.

The health-care industry accounted for 17% of the U.S. gross national product in 2009 (*19*), compared with 5% in 1960 (*20*), and its political and financial clout today is considerable (think military–industrial complex of your day to get an idea of its influence). Health care is now competing—and usually winning—against public health programs and many other public needs for a growing slice of the government budget pie. Since 1961, large national health insurance programs have been implemented (called Medicare for elderly and disabled persons and Medicaid for poor persons), although many Americans remain uncovered. The private medical-care system also has grown tremendously, and large for-profit health systems are a dominant force. Prevention outside of the health-care provider's office gets comparatively little attention or funding. As costs have risen, health insurance financing has become the dominant focus of public policymaking related to health.

Despite—or perhaps because of—the growth of the health-care industry, many public health departments have stopped providing direct clinical services. Most health departments have few clinicians on staff (*21*) and limited influence over or engagement with the inner workings of the health-care system, except in times of large disease outbreaks, which are relatively rare. As a consequence, the gap between health care and public health has widened. Although most health-care providers still look to CDC as an authoritative source of information about health issues, and *MMWR* is widely respected, often the public health system and the health-care system are on independent tracks. Health-care providers, who should be public health's closest collaborators and allies, often have little interaction with and understanding of the public health system.

4. Tobacco use in the United States peaked in 1963.

Per capita cigarette consumption peaked in the United States only 2 years after you read that first CDC-published *MMWR* (Figure 1) (*22*). Although tobacco is still the leading preventable cause of morbidity and mortality in the United States, today only 19% of adults smoke (*23*). This amazing turnaround was achieved through innovative tobacco control and nonsmokers' rights movements that blazed a new path for public health practice, creating a model focused on promoting environmental and policy change, rather than providing individual health education services. So, while in 1961 few public health practitioners would have embraced promotion of a tax as part of their toolbox, today promoting increases in taxation of tobacco products has been effective and is an evidence-based practice. And all around the country health departments have helped pass laws to prevent exposure to secondhand smoke (don't even think about lighting up next time you get in an airplane).

Experience with tobacco control also has demonstrated that comprehensive approaches that support behavior change in a coordinated, synergistic, and reinforcing way are needed to effectively change a complex health behavior like smoking (*24*). Increasingly the public health workforce is developing skills related to this new paradigm. And, because most government public health agencies are constrained in how actively they can pursue legislative advocacy, collaboration with the nongovernment advocacy community has become increasingly important.

5. Tobacco has a serious new competitor for the leading preventable cause of death and disability: obesity.

While you slept, another major driver of chronic diseases snuck up on public health. Obesity has become epidemic in the United States, driving up rates of diabetes, heart disease, and many other chronic health problems (Figure 2). This epidemic has been driven by changes in the ease of making poor food choices and avoiding physical activity. Although each of these changes was small and occurred gradually, in retrospect

FIGURE 1. Chesterfield cigarette advertisement on back of 1953 Metropolitan Opera program, featuring Arthur Godfrey, popular entertainer and smoker who later died of lung cancer.

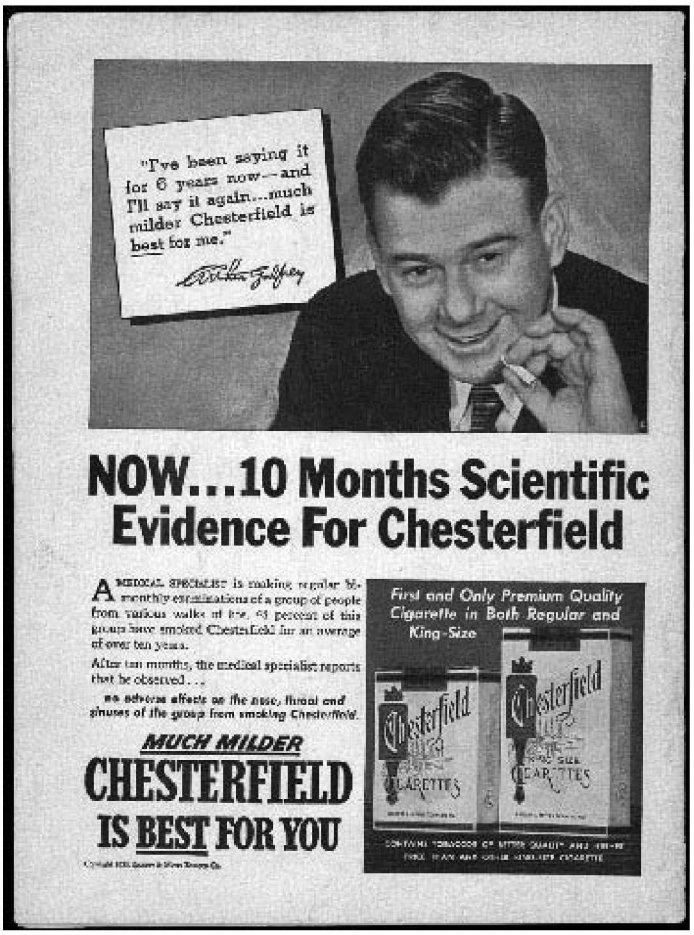
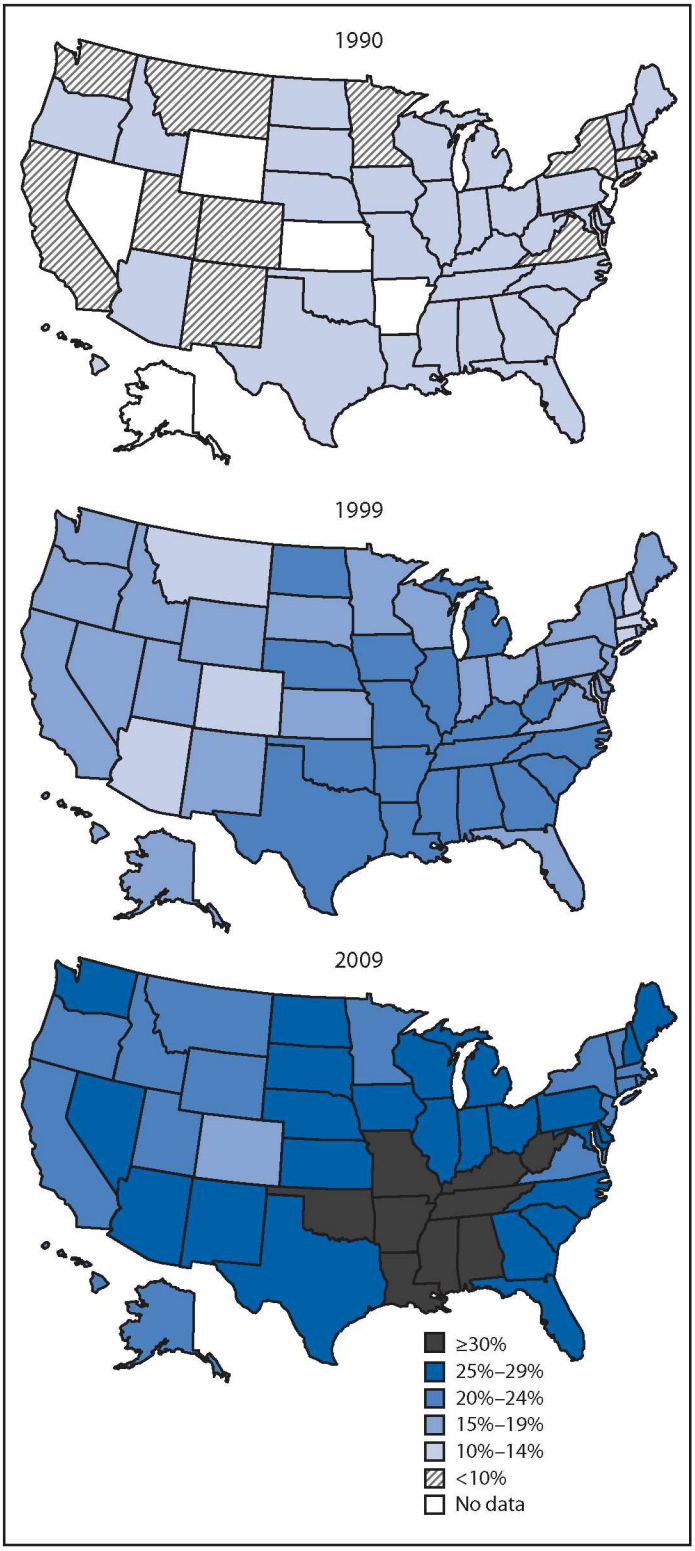


Photo: CDC

their cumulative effect has been dramatic (*25*). For example, concerns about safety now result in most kids being driven rather than walking to schools. U.S. teens consume >10% of their calories from sugar-sweetened beverages (*26*). And the United States has become a nation addicted to large portions (you will not believe how large), quick-to-prepare, inexpensive, "fast foods."Just as tobacco control activities brought public health up against powerful corporate interests, similar battles are brewing with the food industry, and conflict between health and profit will undoubtedly continue to have a major influence on public health practice.

An extensive research base informs tobacco control. However, public health is still learning how to reverse the obesity epidemic and how best to increase physical activity and improve nutrition.

FIGURE 2. Obesity trends* among U.S. adults — BRFSS, 1990, 1999, 2009



Abbreviation: BRFSS=Behavioral Risk Factor Surveillance System.
Source: http://www.cdc.gov/obesity/data/trends.html.
* Body mass index ≥30, or about 30 lbs. overweight for a 5'4" person.

FIGURE 3. Oregon Public Health Agency Operations Center during the 2009 H1N1 Influenza Pandemic.

Photo: CDC

6. Everyone in the health department has a personal computer on his or her desk.

Don't pull out that slide rule you depended on in 1961 or, at best, you'll be viewed as a quaint relic of a bygone era. Powerful computers (machines that rapidly perform calculations, among many other functions) now sit on your desk or your lap and make possible almost instantaneous analysis of data. And new techniques for statistical analysis, unknown in 1961, are widely used today.

These "personal computers" (PCs) also have made possible creation of visual aids for presenting data. Color images and photographs, as well as text and tables, can now be projected onto large screens and easily manipulated and shared, even to excess. Computers also can be used to design and produce photographs and other graphics on paper. Beautiful reports and newsletters can now easily be published from anyone's desk. Curiously, all of this has not improved our presentations as much as you might predict.

Virtually all aspects of life in 2011 have been altered by computers. However, public health practice has one additional unique connection with PCs. One of the richest men in the world made his fortune from creating computer programs for these machines and then donated much of that fortune to a foundation working to improve global health (*27*).

Fortunately, wisdom has not gone the way of your slide rule. Much of what an ace epidemiologist in 1961 knew about data remains critical today. The adage "garbage in, garbage out" still applies, despite the newer statistical manipulations. And, although multiple pathways to statistically significant p values are now well within the reach of even the most junior analysts, just because an association is statistically significant still does not mean it is useful or even true. A 2x2 table still can take you a long way to understanding what the data are trying to tell you.

7. The speed and volume of information flow have increased exponentially since 1961.

Since 1961, an information revolution has occurred. The widespread availability of PCs and cell phones (tiny cordless telephones that work anywhere in the world) has made use of e-mail and text messaging (instant electronic communication between PCs or cell phones) and the Internet (a global, interactive storehouse of information used for almost anything you can imagine) accessible to everyone 24/7 (24 hours a day, 7 days a week, commonly used to describe our availability for doing work in 2011). Not all of that information is good; practitioners today receive lots of e-mail spam (the name of the canned meat that you ate in 1961 has been borrowed to describe unwanted e-mails). Although these tools have increased our connectivity with one another, they also have raised expectations for instant (yet accurate) responses. Practitioners today spend a great deal of time answering e-mail, taking time away from reading and face-to-face interactions, not to mention thought, rest, and vacation.

The creation of the Internet, 24-hour television news, and other communications channels have created an insatiable demand for health information, and public health practitioners are often put on the spot, expected to have that information at their fingertips on a moment's notice. Many are uncomfortable working with the media and ill equipped to play this new role. Public health's culture still values data, science, detail, and subtlety, and that culture makes uttering sound bites (short pithy sentences that play to the new time-compressed media) an unnatural act.

"Social media" tools are also used by today's public health practitioners. These venues are evolving from moment to moment like a Twitter message (don't worry, most current public health practitioners don't really know what Twitter is either) as new tools emerge. Practitioners today commonly use "Google" (an "engine" for searching for information on the Internet) and subscribe to "listservs" (computer services that send correspondence to groups automatically). Even the *MMWR* makes material available through "podcasts" (audio recordings that can be obtained through the Internet and loaded onto portable playback devices).

8. State and local health department employees are increasingly virtual federal staff.

Although no constitutional amendment has yet given the federal government primary responsibility for protecting the public's health, Washington, D.C., rather than state

government, has become the primary source of funding for state health departments (*28*). Federal policymakers have become the dominant force shaping agendas and programs.

This has its advantages. Federal funding has helped drive adoption and standardization of science-based programs. For example, in contrast to 1961, all states and many local jurisdictions have at least some programming in chronic disease, primarily provided by CDC funding (*29*). During the past few years, this federal funding also has partially protected state and local health departments from state budget cuts resulting from the worst fiscal crisis in the United States since the *MMWR* began publication at CDC.

But there are downsides too. Federal funding comes most often through categorical grants (financing for predefined public health programs) (*29*). So even though we have not become farmers, you will hear references to "program silos" that some say inhibit leveraging of resources and creativity. Federal priorities often displace the priorities of states and localities, just because federal grant funds are available. In fact, the dominance of funding for federal priorities has made it easier for state and local elected officials, and even some health departments, to avoid doing their own priority setting. That lack of engagement at the state and local levels has weakened public health practice.

Despite a great deal of federal support, substantial gaps remain in the capacity of most health departments to address important areas of public health practice. For example, although injuries are the leading cause of death for persons aged 1-44 years (*30*), most state and local health departments have limited resources, if any, to address this public health concern. Despite the great increase during the last 50 years in public concern about environmental toxins, few environmental public health programs at the state and local level have been able to go very far beyond the essential services they were performing in 1961, such as restaurant inspections and oversight of drinking water systems and sewage disposal, and include substantial investigations of and research about exposure to environmental toxins in their routine work.

Because of the increasing importance of federal funding in the budgets of state and local public health agencies, federal policy choices about the scope and role of government have a large impact on state and local public health agencies. This makes it especially important for the public health system to be able to articulate what it does and demonstrate its value in ways that are compelling for federal policy makers and the public that elects them.

9. There is an Emergency Operations Center in our basement.

Since 1961, we have gotten better at handling public health emergencies. After the terrorist events of 2001, federal and state governments increased attention and funding for terrorism and emergency management. Other public health events, such as the outbreak of severe acute respiratory syndrome (SARS) in 2003; Hurricane Katrina, which flooded New Orleans in 2005; and 2009 pandemic influenza A (H1N1), helped focus attention on emergencies and how we handle them. Together these crises have led to a massive federal investment in preparedness infrastructure at state and local health departments, aiming to fix the results of many years of neglect of buildings, data systems, and the public health workforce.

The Incident Command System methodology has become the standard of practice for managing public health response in these settings (*31*). Health departments around the country now routinely activate an "Emergency Operations Center" or "EOC" (Figure 3) at the outset of an emergency to identify and oversee the multiple independent streams of work needed to respond competently and ensure routine and clear communications to policy makers and the public, one of the most important elements of effective response.

The incorporation of preparedness into public health practice has not been easy. The less hierarchic and more collaborative culture of public health differs substantially from the more military culture of law enforcement or emergency response, and this cultural divide has created its own set of communication and coordination challenges.

A lot of us have also worried about whether the new emphasis on preparedness activities has diverted resources and distracted attention from our most important day-to-day mission: preventing the major causes of death and disability. For example, despite the dire consequences of the obesity epidemic, much less funding has been made available for obesity prevention work than for preparing for the rare possibility of a terrorism event. On the bright side, the visibility afforded public health in emergency situations, particularly when the public health system is generally perceived to have performed well (as in the 2009 pandemic [H1N1] outbreak), might help the public and policymakers better understand the relevance of public health and build the political will to support public health system in other areas.

10. Our art is becoming science through research and evidence-based practice.

Since 1961, the evidence base for public health programs has grown, but the demand for additional evidence has only increased. Today, to an increasing extent, funders and policymakers want to see proof of our effectiveness and are holding us accountable for the performance of our programs. Groups such as the Cochrane Collaboration (*32*) and the U.S. Task Force on Community Preventive Services (*33*) have helped apply and enhance the rigor of this technique for public health practice and services.

When you fell asleep, public health nursing and home visiting had long been important tools in public health practice, especially at the local level. While you slept, rigorous evaluation has demonstrated substantial impacts of home visiting by nurses, including improved prenatal health, fewer childhood injuries, fewer subsequent unplanned pregnancies, increased intervals between births, increased maternal employment and improved school readiness (*34*). Expansion of these programs is likely to continue to be an important part of local public health practice in the future.

That is just one of many areas in which rigorous research and evaluation have confirmed and refined what state and local public health practitioners do. The refinement and widespread use of meta-analysis has allowed us to pool the results of many small studies and increased the robustness and validity of research findings in many areas. In truth, these efforts also have highlighted the dearth of rigorous evaluation of much of what we do in public health and the standards for acceptable evidence of effective community-based practices are evolving. Increasingly we see the need for practice-based evidence as well as evidence-based practice (*35*) to continue to hone our work. But better science has raised expectations that our work is evidence based and demonstrably effective. In most settings today, personal credibility alone will not drive public health action unless it is coupled with the accumulated and synthesized scientific information available.

The Future

> *"I am your father!" cried he—"Young Rip van Winkle once—old Rip Van Winkle now!—*
> *Does nobody know poor Rip Van Winkle!"*
> *—Washington Irving, Rip Van Winkle* (1)

This retrospective look begs for a brief prospective glance into the future. What if the events leading to the long sleep of our hapless, hypothetical 1961 public health practitioner repeated themselves and he nodded off again, only to awaken in 2061?

Prediction is a risky business. Nevertheless, we'll go out on a limb and venture to predict that many of the trends described above will have continued. More old infectious diseases will be gone or much reduced because we are likely to have highly effective vaccines for malaria, tuberculosis, HIV, and influenza. More new diseases will be identified. The rest of the world probably will have caught up with the developed world in terms of the epidemiologic transition from infectious to chronic disease. Undoubtedly spectacular new information technologies will dramatically transform our lives. And when we are really feeling optimistic we can even predict with some confidence that the obesity epidemic, so long in the making, will be well on its way to being defeated.

On the other hand, in at least three critically important areas of public health practice 50 years from now, the outcomes seem too close to call; the factor that determines whether we are "alone and forgotten"—like Rip Van Winkle—may be us.

1. The need to contain health-care costs could profoundly improve the linkage between health care and public health. Or not.

It is frequently said these days that the rate of increase in the costs of providing health care in the United States is unsustainable. There is less agreement on the solution. Although health-care system improvements will be important, investments in public health systems that support community-based programs to address the determinants of health, improve access to quality health care, and emphasize the delivery of preventive services by the health-care system and at the community level also are needed. Without those investments to address the drivers of the need for health care, the United States will not have a sustainable business model for its health-care system.

The current funding crisis and the potential for investments in public health provide an opportunity for public health to sharpen its focus on the core functions of assessment, policy development, and assurance (*36*) and for the public health and health-care systems to articulate more clearly their complementary roles and link together more closely, closing the chasm between health care and public health and creating one system that truly helps "assure the conditions in which people can be healthy" (*36*). Electronic clinical data systems, if designed with both clinical and state and local public health needs in mind, will support this linkage.

But even though opportunity exists, the outcome in this area is not assured. To reach this goal will require vision, leadership, and a new spirit of collaboration between public health practitioners and clinicians.

2. The structure of our antiquated public health system will have changed, either because of us or despite us.

It has been said that "if you've seen one health department, you've seen one health department" (*37*) to illustrate the wide variation in agency structure, services, budget, and political accountability across the country. Some variation allows us to meet different needs and take advantage of different opportunities across the country. However, in a world that is increasingly interconnected, with instantaneous national and international communication and concerns, the current profound differences in funding and capacity among state and local health departments are likely to be more and more counterproductive.

The huge differences among health departments are inefficient and obstruct efforts to achieve economies of scale, transparency, and reliable system governance. In a time when the public demands evidence of performance and accountability from state and local health departments, these differences make it much harder to explain to the public why we do what we do—which in turn makes advocating for resources and political support much more difficult. New performance standards (*38*) and accreditation processes (*39*) might help bring data on state and local health department performance and capacity to the surface in a standardized way that will facilitate communication and meaningful interpretation, but as in other areas of public health practice, data are only one input into public health action, and the data generated by these tools alone will not power structural changes. They are necessary but not sufficient.

We are pretty certain that 50 years from now the structure of the U.S. public health system will have changed profoundly. The public's health will benefit the most if we embrace the need for change and lead this process rather than dig in our heels about the status quo and allow it to be imposed on public health from the outside.

3. Depending on how well we have addressed the current leading causes of preventable death and disability, government public health agencies will either be empowered or marginalized.

Much of the increase in average life span we have enjoyed over the past 100 years has resulted from such public health programs as immunization, improved sanitation, and public health services for young mothers (*40*). But times are changing, and what we do every day in state and local health departments has been slow to catch up. As rates of death and disease from infections, as well as rates of infant and maternal mortality, fell and rates of death from chronic disease rose, our structure and programs did not evolve well in response to this epidemiologic transition (*41*). Paradoxically our remarkable historical victories place us at increasing risk for becoming victims of our own success because we are viewed as focusing too much attention and resources on causes of morbidity and mortality that were dominant in past decades.

To remain relevant over the next 50 years, we will have to better balance protecting our successes with attacking our challenges. Preventing injury, reducing disability associated with aging, mitigating the effects of global warming, and preventing mental health and substance abuse problems are just a few emerging areas in which public health could make a big difference but currently is not doing enough. Also, the increasing diversity of the U.S. population and the recognition of the profound influence of social determinants of health on health outcomes demand that public health practice at all levels develop and implement coherent and effective strategies to tackle these foundational drivers of health. To meet the demands in these areas at state and local health departments, staff across the system will need to have not only subject-area expertise but also strong skills in changing systems, environments, and policy; using media; building coalitions; and convening and leading a broad array of partners well beyond those of today's public health mainstream.

In summary, the crystal ball is cloudy and public health practice in 2061 is likely to look at least as different from today's practice as today's practice looks from that of 1961. The most profound changes are likely to be the ones that are unimaginable today. Amidst all this uncertainty, perhaps the safest prediction to make is that *MMWR* will be there to tell us about it.

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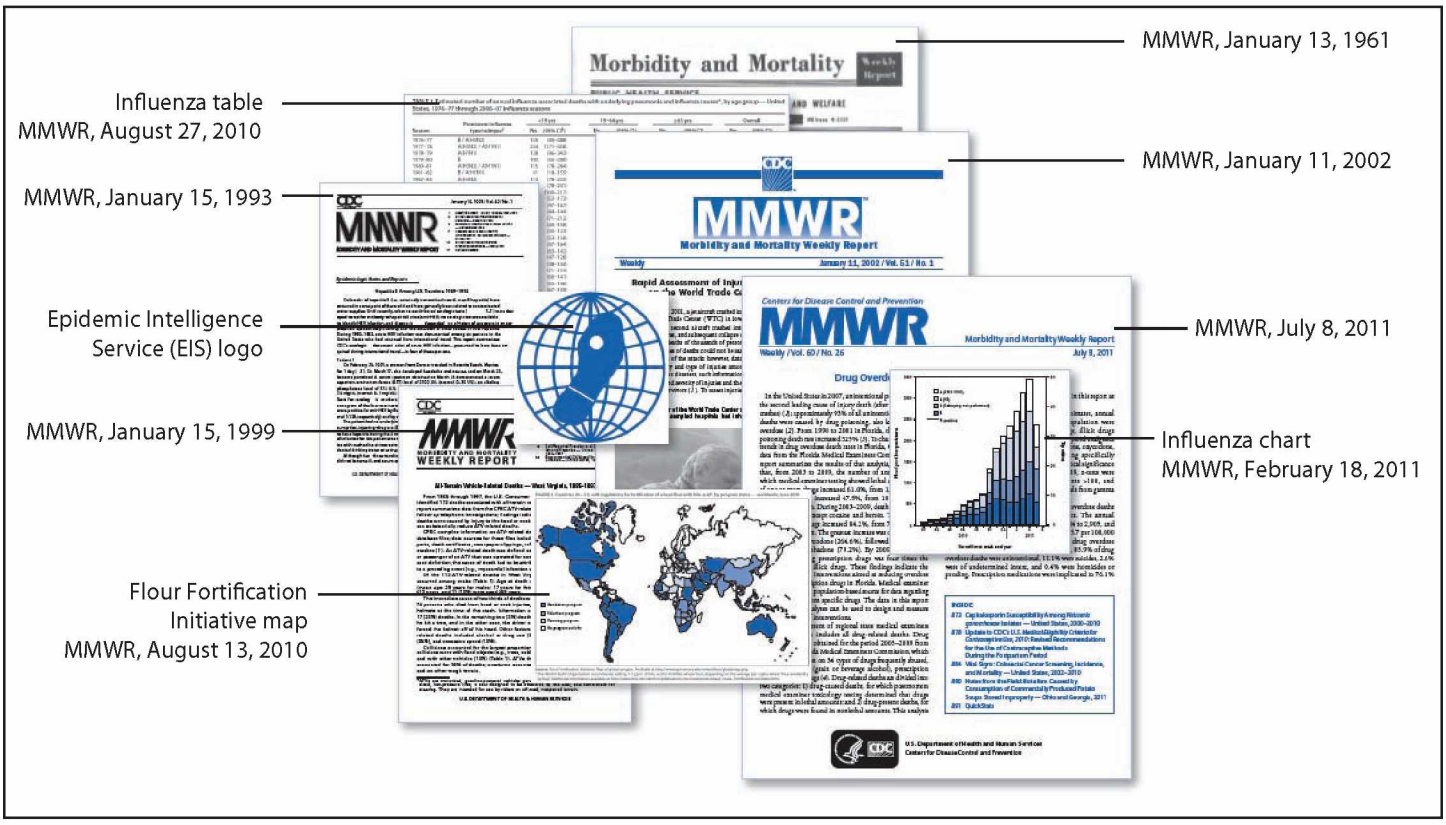
On the front cover: The *MMWR* front pages presented on the cover represent the evolution in the format of *MMWR* during its 50-year history at CDC.



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