CDC WONDER: A Comprehensive On-Line Public Health Information System of the Centers for Disease Control and Prevention

ABSTRACT

Objectives. CDC WONDER, a comprehensive on-line public health information system of the Centers for Disease Control and Prevention (CDC), was developed to place timely, action-oriented information in the hands of public health professionals.

Methods. A unified system was developed de novo to be used for and to evolve along with public health. All data are stored and updated on the CDC mainframe.

Results. CDC WONDER provides menu-driven access to 24 databases with information on mortality, hospital discharges, cancer incidence, notifiable diseases, acquired immunodeficiency syndrome, the *Morbidity and Mortality Weekly Report,* etc.; each database has on-line documentation. Results can be tabulated and graphed, and there is full-text searching of textual databases. Non-CDC staff have access via telephone connection. From August 1991 through June 1992, system databases were accessed 10 698 times, and there were 842 users (mean of 97 new users per month).

Conclusions. CDC WONDER has shown that it is possible to build a large, on-line database of scientific data for public health professionals. CDC WONDER provides a common foundation from which to build information-based public health plans and policy and could help strengthen the public health system. (*Am J Public Health.* 1993;83:1289–1294)

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Introduction

To successfully take on the public health problems of the 1990s—environmental contamination, chronic disease, infant mortality, HIV (human immunodeficiency virus) infection, and AIDS (acquired immunodeficiency syndrome)—we need new systems to provide ready access to detailed, timely, action-oriented information. The Institute of Medicine's report *The Future of Public Health* recommends that public health agencies "make available information on the health of the community, including statistics on health status, community health needs, and epidemiologic and other studies of health problems."[1(p7)] This information must be accessible and useful to public health practitioners at the local, state, national, and even international levels of decision making.

In this report, we describe a mechanism that has been developed by the Centers for Disease Control and Prevention (CDC) to place that information in the hands of public health professionals. CDC WONDER (Wide-ranging ONline Data for Epidemiologic Research), a comprehensive on-line public health information system, was developed to make it fast and easy for public health professionals to access information from a wide variety of sources, including surveys and surveillance systems, specialized studies, the *Morbidity and Mortality Weekly Report (MMWR),* and descriptions of state and local health department activities; and to have this information in a form that can be readily used to design prevention strategies and better allocate resources for services and research.

Background

The development of CDC WONDER was stimulated by a desire to help public health benefit from the Information Age. The new mainframe and minicomputer statistical analysis packages of the 1970s and the advent of the personal computer in the 1980s prompted public health professionals to do their own computer programming; by the mid-1980s, many were becoming buried in the arcana of manipulating numbers and had less time for public health research and practice. Simultaneously, improvements in software and hardware made possible surveys and studies of unprecedented size and complexity, forcing many epidemiologists to become data managers as well.

These large surveys have generated new interest in the analysis of "secondary" data. These data come from dozens of sources, and identifying and selecting appropriate data can be daunting. Each data set has strengths and weaknesses to which the analyst needs to be alerted; for example, many data are drawn from complex surveys that require the use of special statistical techniques for analysis.[2]

CDC WONDER was also designed to simplify the management of data from surveillance and survey systems. These data are obtained from state and local health departments and community-based agencies that use the data to plan and evaluate prevention programs, request funding from legislatures and other granting

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sources, and carry out research. However, verifying the data, communicating with data providers, and releasing results are time-consuming and labor-intensive. Moreover, although health departments are increasingly able to do their own data analysis instead of relying on federal reports, which may lack geographic detail or information on locally "hot" issues, resources for this work at local levels are often limited.

Thus, by the mid-1980s, many public health workers were spending much time identifying data, writing programs to extract key data and analyze them, and using remaining hours to draw conclusions. At the same time, local agencies were often dependent on others for informational needs.

To address this problem, in 1987 we conceptualized an information system designed to refashion the work paradigm of public health researchers, managers, and decision makers. The system would be a tireless and nearly faultless 24-hour-a-day programmer/assistant; however, it would know more than any one person ever could and would provide analytic services without sacrificing the instant feedback of hands-on work. CDC WONDER's databases would include almost all the information that public health researchers would need for routine work. Our short-term goal was to facilitate information-driven public health decision making. Our long-term goal was to change the way CDC collaborators in government, academia, and private industry access, analyze, and communicate public health information. In designing CDC WONDER, our goal was to enhance information access while retaining flexibility and independence for the analyst.

Methods

Alternative Strategies

We evaluated two strategies for building CDC WONDER: (1) creating a network of existing computer systems, or (2) designing a new integrated system de novo and later connecting it to existing systems. The network solution would have involved linking data retrieval systems located at computer centers in government and academia. This approach had the advantage of making use of existing systems; thus, the burden of maintenance and enhancements would have been borne by others, and CDC WONDER might have gotten off to a faster start. However, the disadvantages outweighed the benefits. First, CDC would have been dependent on others for a mission-critical system and might not have developed expertise in scientific database systems. Second, users would have had to learn many interfaces. Third, the CDC would have been dependent on others to build primary information systems. Moreover, there was no way to ensure that others would create information systems specifically for public health and that these data would be made available in the right formats and on the required schedules. As a variation of the network idea, we considered developing standards for interfaces and communication protocols that others could adopt. However, we could not provide strong motivations (e.g., funding, access to user or data, technical facilities) to encourage disparate agencies to either follow standards or enhance data for CDC's needs.

The second approach was to build a unified information system de novo. The critical advantage here was that such a system could be designed for and to evolve with public health. The overall design and central programming would be coordinated by one group, promoting standardization while facilitating system-wide enhancements. Users would need to learn only one interface. CDC would also become more knowledgeable about scientific information systems. Thus, despite potentially higher costs and the need to develop expertise in a new field, CDC opted to develop a unified system.

Building CDC WONDER: Software

Once the decision was made to develop an in-house system, the CDC had to choose whether to "buy or build." In 1985, the CDC had purchased access to an on-line database of sociologic, demographic, and environmental information.[3] Although it offered access to large files, the database was slow and hard to use, and it did not offer a straightforward way for the CDC to add data. In 1987, we developed the first prototype of CDC WONDER in SAS (Statistical Analysis System, SAS Institute, Cary, NC). In 1989, this version was made available to the CDC staff; it provided menu-driven access to data on mortality, AIDS, and behavioral risk factors. Data were stored on the CDC mainframe in Atlanta. All functions were available via menus and fill-in-the-blank screens. (Previously, access to these data required complex end-user programming.) Users could generate tables, charts, and maps.

However, user feedback indicated that, for CDC WONDER to be used more widely, retrieval would need to be faster and more flexible, the interface would have to be easier to use, and the screens would have to change more quickly than the current duration of 10 to 20 seconds. CDC WONDER was therefore rewritten using the database ADABAS and the language Natural (Software AG, Reston, Va), which provided faster data access, and customizable screens that changed quickly. SAS continued to be used to generate charts, maps, and SAS and operating system data sets, but users used a single, unified interface for all functions (whether ADABAS or SAS was performing the underlying work). In January 1990, an improved version of CDC WONDER, which used this new software and incorporated many user suggestions, was released; it is now described more fully.

Results

System Features

CDC WONDER is an on-line information system that allows a user to query data via menus (see Figures 1 and 2); no computer programming is required. All data reside on the CDC/Atlanta mainframe and are updated on an ongoing basis. CDC users can view all of the results on the screen or print them on a CDC printer. Non-CDC staff can access CDC WONDER via modem connected to a telephone line using CDC-supplied software. Tabular and textual results can be viewed on screen and can be downloaded to a microcomputer for further analysis, editing, and printing. Almost all queries take less than 3 seconds. Context-sensitive help is available throughout, and there is a staff to provide user support.

Every CDC WONDER data set has on-line documentation—for example, information on how the data were collected, the precise phrasing of the question on a questionnaire, sampling methods, known biases and errors, and references. Experts were invited to supplement this information with their own commentary.

CDC WONDER has a special facility to search through textual databases such as the *MMWR*, documentation for numerical data sets, or data sets that consist of preformatted tables (see the next section). This system does not depend on keywords; rather, it searches for words or phrases that appear anywhere in the text, including in the titles of tables. Search terms can be truncated (e.g., searching on "alco*" is equivalent to searching on "alcohol or alcoholic or alcoholism," etc.),

Underlying Cause of Death

Select Data:

Years	(79-88)	= 79 - 88	
Age Code	(1-17)	= 1_ - 17	(All Ages)
Race	(W, B, O)	= B	(Blacks)
Gender	(M, F)	= F	(Females)
State/County		= 01000	(Alabama)
ICD-9		= 174-174.9	

(Malignant Neoplasm of Female Breast)

Output:

By: County

Rate per: 100,000

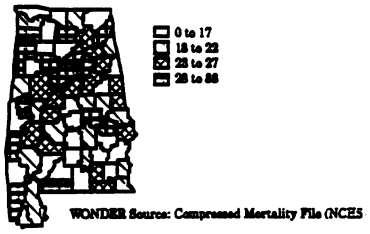
Death Rate/100,000, Blacks Females, 1979-88, Alabama
Malignant Neoplasm of Female Breast (Deaths=1,401. Rate=25.3)

	County Name	Pop x Years	Deaths	Death Rate	Histogram
1	Dekalb	4,495	4	89.0	----------
2	Franklin	6,189	5	80.8	----------
3	Lamar	9,649	6	62.2	----------
4	Marion	3,262	2	61.3	----------
5	St. Clair	24,340	9	37.0	-------
6	Escambia	58,300	20	34.3	-------
7	Greene	46,788	16	34.2	-------
8	Walker	27,118	9	33.2	------
9	Blount	3,074	1	32.5	------
10	Morgan	52,489	17	32.4	------

etc...

Death Rate/100,000, Black Females, 1979-88, Alabama(Deaths = 1,401-, Rate = 25.3)

Malignant Neoplasm of Female Breast



WONDER Source: Compressed Mortality File (NCES

FIGURE 1—Using CDC WONDER to retrieve, tabulate, and map underlying cause of death data: female breast cancer, Blacks, Alabama, 1979 through 1988.

MMWR Articles Search

Use this screen to search the MMWR articles dataset for words/phrases in the title/text and/or ranges of issue numbers or dates.

Word(s) /Phrase(s): (Use wildcard: ALCO* = ALCOHOL, ALCOHOLIC)

BREAST CANCER ____- or - CARCINOMA OF BREAST_____

AND FEMALE _____

AND Source: Volume ____through Volume ____(Vol 31 - 40)

Issue ____ Issue ____

Page ____ Page ____

OR Date:__/__/__ through __/__/__ (1982 - 1992)

MMWR Articles Found

S 06/26/92 Public Health Focus: Mammography

__ 06/19/92 Publication of CDC Surveillance Summaries

__ 06/19/92 Selected Tobacco-Use Behaviors/Dietary Patterns

__ 03/27/92 Assessing the Effectiveness of Prevention

__ 07/19/91 Current Trends of Cardiovascular Disease

etc...

Public Health Focus: Mammography

Among U.S. women, **breast cancer** is the most commonly diagnosed cancer and the second leading cause of death from cancer. From 1980 through 1987, the incidence of **breast cancer** increased from 94.6 to 124.3 per 100,000 women (age-adjusted to the 1990 U.S. population). In contrast, death rates remained stable; during 1988, 31.1 per 100,000 U.S. women died from the disease. Although the prognosis for **breast cancer** is more favorable than for many other types of cancers, **breast cancer** continues to be an important source of years of potential life lost before age 65.

etc...

FIGURE 2—Using CDC WONDER to search the *Morbidity and Mortality Weekly Report (MMWR)* for articles that contain "breast cancer" or "carcinoma of the breast" anywhere in the text.

and synonyms can be added to the system (e.g., searching on "HIV" was made to be equivalent to searching on "HTLV III"). Search terms can be single words or phrases and, if "ANDed" together, can be required to appear within a certain number of words or sentences, or in a specified order.

CDC WONDER has a special subsystem to look-up *International Classification of Diseases* (ICD-9) codes. It works by searching the full index (vol 2) and then displaying a list of codes associated with the search term. For example, searching on "lung cancer" finds "malignant neoplasm of main bronchus (162.2)," "of upper lobe (162.3)," etc. (Note that "lung cancer" itself is not a term found in the *ICD-9* system). Each code has 20 to 120 search words associated with it; for example, 162.3 is associated with lung, neoplasm, cancer, tumor, etc. The system also includes codes from the *ICD-9*'s clinical modification version (*ICD-9-cm*) and procedures (vol 3) for use with data other than mortality data.

Data

At its initial release in January 1990, CDC WONDER had four data sets; by June 1992, there were more than 20 (Tables 1 to 3). Data are derived from standard public use files, data prepared especially for CDC WONDER, or printed tables that were converted into electronic format. Four types of data are available. The first type is large numerical data sets (Table 1), from which the user can create multiway tables, bar charts, county-level maps, and customized subsets for further analysis with other software. (For technical reasons, users accessing the system via remote dial-up modem connection cannot obtain graphics and data subsets). The second type is preformatted tabular data sets (Table 2), consisting of tens of thousands of tables that can be searched, read, and printed but not otherwise manipulated.

TABLE 1—Numerical Databases Currently in CDC WONDER (as of June 1992)

Subject	Data Set	Agency	Period
AIDS	Microfiche data	CDC	1983–12/1991
AIDS	Public use surveillance data	CDC	1983–12/1991
Behavior	Tobacco use data, National Health Interview Survey	CDC	1987
Cancer	Pap smear data, National Health Interview Survey	CDC	1987
Cancer	Surveillance, Epidemiology, and End Results	NIH	1973–1988
Census	Population by age, race, gender, county	Census	1970–1990
Hospitalization	National Hospital Discharge Survey	CDC	1985–1990
Mortality	Underlying cause of death	CDC	1979–1988
Mortality	Multiple causes of death	CDC	1987–1988
Mortality	Occupation-related causes of death	CDC	1960–1989
Mortality	Underlying cause of death: England & Wales	OPCS	1986–1990
Notifiable diseases	National Notifiable Diseases Surveillance Systems	CDC	1989–1990
Sexually transmitted diseases	Sexually transmitted diseases surveillance	CDC	1989

Note. CDC = Centers for Disease Control and Prevention, NIH = National Institute of Health; Census = Bureau of the Census; and OPCS = Office of Population Censuses and Surveys, UK.

TABLE 2—Tabular Databases Currently in CDC WONDER (as of June 1992)

Subject	Data Set	Agency	Period
Alcohol	Alcohol abuse and alcoholism data county indicators	ADAMHA	1900–1990
Behavior	Behavior Risk Factor Surveillance System	CDC	1989
Diabetes	Diabetes surveillance and state fact sheets	CDC	1980–1990
General	Health US	CDC	1900–1989

Note. ADAMHA = Alcohol, Drug, and Mental Health Administration; CDC = Centers for Disease Control and Prevention.

TABLE 3—Text Databases Currently in CDC WONDER (as of June 1992)

Subject	Data Set	Agency	Period
ASTHO	Association of State and Territorial Health Officers and affiliate organizations	CDC	Current
CDC experts	CDC Resource Index	CDC	Current
Codes	*International Classification of Diseases-9*	CDC/WHO	1979–present
Codes	*International Classification of Diseases-9-CM*	HRSA	1979–present
Documentation	Documentation on public use data	CDC	1970–present
MMWR	*Morbidity and Mortality Weekly Report*	CDC	1982–present
Health services	National Profile of Local Health Departments	NACHO/CDC	6/1990

Note. CDC = Centers for Disease Control and Prevention; WHO = World Health Organization; HRSA = Health Resources Services Agency; NACHO = National Association of County Health Officials.

The third type is textual data (Table 3), made up of diverse materials such as the full text of the *MMWR*, listings of CDC personnel, and organizational listings. This type also includes the full documentation for several dozen data sets for which the data themselves are not in CDC WONDER, including most of the public use data made available by the CDC's National Center for Health Statistics and specialized population estimates prepared for the CDC by the Bureau of the Census. The fourth type of data is a stock of dozens of SAS data sets derived from large health surveys; output is restricted to subsets analyzable with SAS or other software. (For technical reasons, this fourth category too is available only to directly attached users.)

Data are prioritized for inclusion in CDC WONDER on the basis of current and expected usage; this is ascertained by studying usage both from standard files on the CDC/Atlanta mainframe and in CDC WONDER, by canvassing users, by presenting CDC WONDER at conferences and gathering input, and by studying comments from current users. To determine how best to configure each data set, a panel of "experts" is created, made up of data providers and heavy users of a given data set. Candidate panelists are identified by studying usage patterns of raw data on the CDC mainframe and are selected so as to ensure representation of many public health disciplines. Panelists select the variables to be included (e.g., for mortality data, place of occurrence vs residence), class the variables (e.g., 5-year age groups vs single year of age), and design reports (e.g., two-way tables, standardized rates, maps). A larger number of variables, finer categorizations, and elaborate features require more time to program and sometimes result in slower response time; our experts have guided us on providing maximal useful information within the boundaries of available resources.

In all cases, the data provider always retains full control of both the data and the form of its release. After a data set is added to the system, users are polled to determine which features are most useful, and they are requested to suggest new ones. Over time, many of these user-suggested enhancements have been implemented, including standardization of rates, more multiway tabulations, and finer classifications of age and race.

Confidentiality

Special consideration is given to preserving confidentiality. First, names and addresses are never made available. Second, the CDC works closely with data providers to ensure that individuals cannot be identified inadvertently by matching demographic criteria with identifying characteristics that could be ascertained by other mechanisms; how this is handled depends on the specific data set. For example, AIDS surveillance data are made available via two parallel systems: one system provides case counts by relatively fine geographic detail but provides no information on associated medical conditions; the other system provides just the opposite. In both systems, the value for cells with fewer than six individuals is replaced with an asterisk, and the associated

subtotals are blanked out. (These rules were created jointly by the Division of HIV/AIDS, National Center for Infectious Diseases, CDC, and by representatives of the Council of State and Territorial Epidemiologists, whose members report the data to the CDC.)

Similarly, some reports from data derived from sample surveys (e.g., the National Hospital Discharge Survey) may have cells that contain values with high estimated variances; these unstable values are also replaced with asterisks. In this case, providing the data in CDC WONDER enhances the reliability and quality of available information over that available in the files of raw data. Because these kinds of edits are done within the computer programs, updates are quick and accurate.

All users have equal access to all data. There is a system to grant different levels of access to different users, but its implementation has not been requested by any data providers. Some data providers have requested a description of how their data are used; counts and affiliations (e.g., "CDC staff," "journalist," "state health department") of the users are provided without users being identified by name.

Usage

CDC WONDER was made widely available outside the CDC in August 1991. From August 1, 1991 to June 30, 1992, system databases were accessed 10 698 times (a mean of 972 times per month), and there were 842 users (a mean of 97 new users per month). The most actively accessed systems were mortality, documentation, *MMWR*, and census (Figure 3).

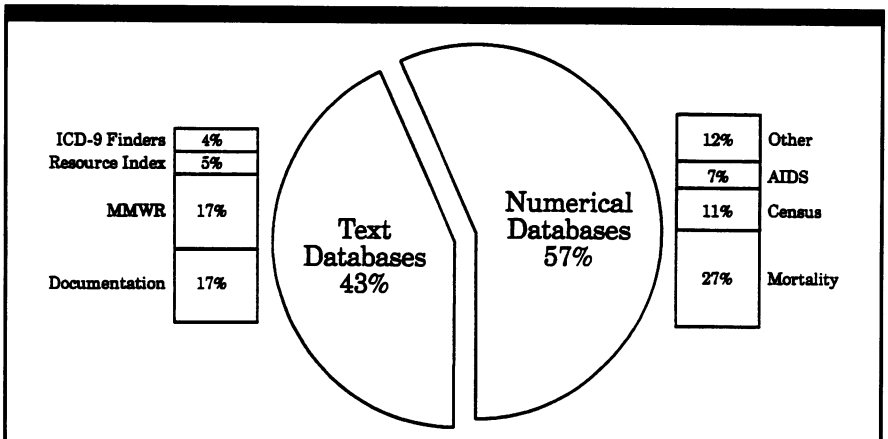


FIGURE 3—Data set usage in CDC WONDER: August 1991 to June 1992 (n = 10 698).

Discussion

The creation of CDC WONDER demonstrates that it is possible to build a large, unified, on-line database of scientific numeric and text data that public health professionals will find useful. CDC WONDER's impact is being felt at the CDC and in state and local health departments. Previously, access to complex data sets was limited to specially trained programmers; CDC WONDER provides nonprogrammer scientists and managers with easy access to information on mortality, population counts, AIDS, cancer incidence, hospitalizations, alcohol abuse, and CDC and state health department activities. Additionally, there are savings in mainframe resources and programmer time, and errors are reduced. Finally, the full-text searching system facilitates more thorough searches than a keyword-dependent system does, not only because keyword assignment depends on judgment but also because keywords are necessarily limited in number and scope.

The usefulness and general applicability of CDC WONDER are demonstrated by the fact that some data providers are among its heaviest users; they sometimes find it easier and faster to use CDC WONDER than to use their own printed reports or report-generating programs. CDC departments and other public health service agencies have found that CDC WONDER provides a way for them to showcase their own data; over the long term, this may encourage the development of better data and information systems and may lead to more collaborations in public health work, including the joint development of information systems that cut across agencies. Indeed, state health departments and the ministries of health in China and Australia have expressed interest in implementing their own (scaled-down) WONDERs. Ultimately, investing in information systems must be justified by reduced costs and/or improved productivity. Now that information system developments are maturing, cost-effectiveness/cost-benefit analyses of their contributions to public health are becoming feasible and should be a subject of future research.

The creation of systems such as CDC WONDER, especially if they are interconnected, raises concerns about data confidentiality.[4] However, more information can be afforded to users by offering multiple controlled "views" of a given data set, wherein the degree of detail presented in the results is a function of the user's identity, than can be offered via traditional methods. Similarly, CDC WONDER can provide different levels of access to different users. For example, state vital registrars, who collect data on births, deaths, and fetal deaths, may wish to share provisional data with each other before such data are otherwise released. Similarly, participants in a large collaborative study may wish to make results from one part of the study available to a certain group of collaborators and to provide other data to different colleagues.

Future Directions: Cooperative Processing for Cooperative Work

CDC WONDER is a one-way (access-only) system and hence has inherent limitations. Public health is a collaborative enterprise, and the next version of CDC WONDER has been designed to align the information architecture to fit the discipline. This new version (which was released in 1993) provides two-way (and multiway) data communications and has three major new features.

First, it provides a mechanism for research and surveillance collaborators to transmit data to the CDC's mainframe or to any local area network–based application, where the data can be verified, interpreted, and added to centralized databases. Feedback to the data provider can be provided within a few minutes and may consist of an analytic summary, comparison with other data, or a listing of discrepancies.

Second, the new system has "electronic mail," which is linked to the CDC's internal electronic mail system and connects non-CDC staff to each other. Computer files of any kind can be "attached" to the mail; for example, a computer file containing a draft manuscript or preliminary data can be distributed, facilitating collaboration.

Third, this new version provides enhanced analytic facilities. Although

source data will continue to be stored on the mainframe, a file of extracted results can be downloaded to a microcomputer where CDC WONDER software can be used to create tables, graphs, or maps, or to export results to spreadsheet, database, or graphics programs. The CDC has devoted resources to writing analytic software (despite the availability of commercial products that perform similar functions) to be able to provide software that is specifically designed for public health.[5] For example, CDC WONDER "knows" what a Federal Information Processing Standard Geographic Code is and calculates directly standardized rates, features that may be absent from commercial software. Taken together, these new functions serve the collaborative mode of public health work and help to integrate public heath activities.

Obtaining Access

CDC WONDER is now available to all public health professionals. Registration materials and software are available from the first author. Currently, there is no cost for using CDC WONDER, and there is a toll-free phone number for accessing the system. Required equipment includes a DOS-based microcomputer and a modem. CDC WONDER users will be notified when the next version of CDC WONDER is available.

Conclusion

CDC WONDER makes it fast and easy for hundreds of public health professionals to obtain and analyze information. By putting information in the hands of decision makers, it could help strengthen and unify the worldwide public health community; by providing scientists, managers, and future public health professionals with access to information that is otherwise very time-consuming and expensive to obtain (if it can be obtained at all), it should open new areas of investigation. Most importantly, CDC WONDER provides a common foundation from which to build data-based public health plans and policy, and thus it could be a critical component of efforts directed at strengthening the public health system.[6] □

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