Surveillance of Foodborne Disease I. Purposes and Types of Surveillance Systems and Networks

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ABSTRACT

This is the first part of a four-part series on foodborne disease surveillance. Although these articles are primarily built on expertise gained within North America, the substance is of value to any community or country wishing to initiate or improve its surveillance system. Foodborne disease surveillance is necessary for preventing further spread of foodborne disease and includes identifying and controlling outbreaks at the time they are occurring; gathering data on incidence of these diseases and prevalence of their etiologic agents, vehicles, and reservoirs; identifying factors that led to the outbreaks; providing a data bank for HACCP systems and risk assessments; estimating health and economic impacts of foodborne diseases; and providing information upon which to base rational food safety program goals and priorities. Reports of outbreaks by local health agencies to regional and, then, national agencies responsible for disease surveillance, laboratory isolations of certain foodborne pathogens from human beings, sentinel community studies, and hazard surveillance are the types of foodborne disease surveillance activities that are used to varying extents in Canada and the U.S. In recent years, some national surveillance reports have been collated internationally in Europe and Latin America. Surveillance at local, state/provincial, national, and international levels must be coordinated for effective and rapid transfer of data. Computer software can assist investigation and management of the information submitted through surveillance networks. Information summarized on individual reports usually includes (a) location of the event, (b) clinical data, (c) epidemiologic data, (d) laboratory findings, and (e) results of on-site investigations. Each outbreak report should be subjected to critical review before classifying it into the various categories of surveillance data. Such a review would also be useful when comparing surveillance data from different places and intervals. Highlights of individual reports are tabulated as line listings that are the direct sources of surveillance data, which are the subject of the second and third parts of this series.

Key words: Foodborne diseases, food poisoning, epidemiology, surveillance

Surveillance of foodborne disease is an important component of food safety programs at all levels of government and within each type of food industry. The few reviews available on this subject (a) emphasize surveillance data of a country (3, 4, 84, 88) or a geographic region (51); (b) describe the approach in general terms (36, 37, 89); (c) discuss the philosophy and implementation of surveillance of diseases but not specifically of foodborne diseases (81, 82, 92); or (d) point out limitations of the existing data (2, 10, 15, 23, 48, 86).

The word surveillance is derived from the French word surveiller, which means to watch over (a person or area), presumably for the purpose of direction, supervision, or control. According to Langmuir (54), surveillance, when applied to a disease, means the continued watchfulness over the distribution and trends of incidence through systematic collection, consolidation, and evaluation of morbidity and mortality reports and other relevant data. Intrinsic to this definition is the regular dissemination of the basic data and interpretations to all who have contributed and to all others who need to know. In 1986, the Centers for Disease Control (26) defined public health surveillance as the ongoing, systematic collection, analysis, and interpretation of health data 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 of the surveillance chain is the application of these data to prevention and control.

A surveillance system includes a functional capacity for collection, analysis, and dissemination of data linked to public health programs. The manual Control of Communicable Diseases Manual, 16th ed. (7) states that surveillance implies the continuing observation of all aspects of the occurrence and spread of disease that are pertinent to its control. More specifically, surveillance of foodborne disease
is a continuous and systematic process that consists of (a)
receiving notification of illnesses, (b) investigating incidents
and reporting findings, (c) collating and interpreting data,
and (d) disseminating information to effect control of current
problems and to provide guidance for preventing the dis-
Eases in the future. Activities associated with (a), (b), and
portions of (c) are described in the International Association
of Milk, Food, and Environmental Sanitarians (IAMFES)
manual, Procedures to Investigate Foodborne Illness, fourth
ed. (17). The last component (d) and certain aspects of (c)
are, however, only briefly described in that document.
Medical and scientific literature provides little information
on or guidance on setting up foodborne disease surveillance
systems, suggesting improvements for presenting tabular
data, or using the data to improve food safety programs.

Unfortunately, foodborne disease surveillance is often
carried out poorly, where it is done at all, and the findings
of many investigations are of insufficient quality or interest for
submitting reports and, therefore, remain in the office where
the investigation was initiated. The Centers for Disease
Control and Prevention (CDC) have described the current
lack of resources for surveillance and investigation of
foodborne disease and the lack of laboratory resources and
methods to identify both known and emerging foodborne
disease pathogens (28). The CDC cited a Council of State
and Territorial Epidemiologists survey that found 12 states
that had no professional position dedicated to surveillance of
foodborne and waterborne diseases. Furthermore, previ-
sely unknown pathogens are being identified at a time
when both resources and number of personnel available for
foodborne and waterborne disease surveillance are insuffi-
cient (46). These situations mean that public health practitio-
ners need to strengthen their efforts to establish and imple-
ment foodborne disease surveillance systems.

This four-part series (a) documents the need for, and the
value of, an effective foodborne disease surveillance system,
(b) describes foodborne disease surveillance systems for
various jurisdictions of the surveillance network, (c) cri-
tiques existing systems and recommends improvements, (d)
gives suggested formats for summarizing foodborne disease
surveillance data, (e) describes ways to disseminate the data
and their interpretations, (f) cites ways in which foodborne
disease data can be used to improve food safety programs,
and (g) makes recommendations for improving foodborne
disease surveillance. The first part of the series presents the
rationale for foodborne disease surveillance, describes sur-
veillance networks, reviews surveillance aids, illustrates
forms for summarizing investigative data, and gives criteria
for critically reviewing investigative reports before accept-
ing them for summarization.

**REASONS FOR FOODBORNE DISEASE SURVEILLANCE**

There are several reasons for foodborne disease surveil-
lance. These include (a) preventing further spread of disease,
including controlling outbreaks as they occur; (b) gathering
data on the incidence of foodborne diseases and the preva-
ence of the etiologic agents, vehicles, and reservoirs,
including identifying factors that contributed to the out-
breaks on which preventive measures and educational
activities ought to be based, and by so doing, providing a
data bank for designing HACCP systems and preparing risk
assessments; (c) estimating health and economic impacts of
foodborne diseases; (d) anticipating problems and focusing
research in areas of high risk; (e) evaluating the effective-
ness of current preventive and control practices; and (f)
providing information upon which to base rational food
safety program goals and priorities.

**Taking prompt control actions.** Once a food responsible
for an incident of foodborne disease has been identified
during an investigation or review of surveillance data,
additional cases can be prevented by taking action to prevent
further consumption of the implicated food. Information on
situations that contributed to contamination of the food or to
survival and/or growth of the causative foodborne pathogens
should be used to implement immediate preventive and
control actions in the place(s) where the implicated food was
(were) processed, prepared, and/or stored. For example, a
Salmonella typhi, Shigella or hepatitis A virus carrier might
de be detected and restricted from handling foods until there is
evidence that the person is no longer shedding the pathogen.

Disease surveillance that links a case of botulism to a
commercially produced food can result in public recalls to
prevent additional cases. An example of a specific outbreak is
the case of two infants identified with salmonellosis in
British Columbia (56). Both had been fed a commercial
infant formula that, when analyzed, was found to be positive
for Salmonella tennessee. A third child in the United States
acquired this serotype from the same lot of powdered milk.
This serotype was also isolated from production equipment
in the manufacturing plant. The product was recalled,
predent cases. Alerts should be disseminated to national, state/provincial, and local health and agriculture
agencies that have regulatory authority over the implicated
food and to the segment of the food industry that may be
affected. Remaining foods or lots that have been epide-
mically identified or laboratory-confirmed with a pathogen
should be detained for appropriate laboratory analyses and,
then, disposed of or reprocessed to kill the pathogens,
denature the toxin, or otherwise eliminate the contaminants.
Where the public is at risk from eating the implicated food,
actions should be taken to prevent further consumption,
which may include public alerts via the mass media.

Appropriate information about the etiologic agent should be
disseminated promptly to the medical community and
diagnostic or food-testing laboratories to aid in treating
cases and in detecting additional cases, vehicles, and reser-
voirs. If a commercially produced food causes illnesses in
one country, health agencies in other countries, where the
food is distributed, should be informed as soon as practi-
cable. Hence, surveillance serves as an early alert of disease in
a community, region, or nation and should trigger prompt
action for control and preventive activities. Incidents not
reported go unnoticed, are often underestimated, and may
result in haphazard preventive measures. Therefore, without
an effective surveillance system, an early alert of an
outbreak may not be possible, and control measures will not
be implemented, or implementations of such measures will be delayed significantly.

Interpreting trends in foodborne disease. Foodborne disease surveillance data (incubation periods, signs and symptoms, durations, and severity, particularly in persons at high risk) are used over time to describe the clinical features of etiologic agents. Incidence of outbreaks, cases, fatalities, and prevalence of etiologic agents associated with outbreaks and isolations of pathogens from human beings show trends over sufficiently long durations. As previously unrecognized foodborne pathogens are identified, they are added to the list of known pathogens. These become the subject of subsequent investigations and of studies of their pathogenicity, ecology, and methods of detection. Some become significant etiologic agents (e.g., *Escherichia coli* O157:H7, which was first recognized as a foodborne pathogen in 1982 [71]). Disease surveillance data can indicate which foods are likely to be vehicles of foodborne pathogens. Newly identified vehicles may indicate changes in practices that lead to contamination, survival, and/or amplification of etiologic agents or formulations that influence these events. Accumulation of data on reservoirs can suggest needs for modifications in agricultural, food processing, and food preparative practices or education in personal hygiene. Furthermore, surveillance data can show patterns associated with (a) contamination, (b) means by which the contaminants survived or increased, and (c) populations at risk of severe outcomes. They can identify the chain of events from contamination to the final product. Risks of illness can be estimated on the bases of foods coming from known reservoirs and processed or prepared hazardously.

Identification of factors that affect contamination, survival, and growth of the etiologic agents is necessary for effective preventive or control actions to be taken. If the practices are commonplace in the food industry, widespread alerts, prompt preventive measures, and changes in regulations are warranted. Focus for ongoing food safety programs can be provided by a data bank reflecting the relative importance of (a) sources and modes of contamination, (b) types of processes and methods of preparation that may allow survival of pathogens, and (c) means by which the bacterial or fungal pathogens proliferated. Surveillance information is useful in estimating risks of illness and in determining critical control points when setting up and verifying hazard analysis critical control point (HACCP) systems for ensuring food safety [18, 91].

Determining consequences of foodborne illness. Health and economic impacts of foodborne disease can be estimated from surveillance data. Special follow-up studies of foodborne illness victims weeks, months or even years after an acute illness can identify chronic disease conditions such as hemolytic uremic syndrome, reactive arthritis, rheumatic fever, and Guillain-Barré syndrome. These ailments can severely limit the lifestyles of these persons and may require ongoing medical attention. Such data can be extrapolated to produce estimates of the consequences of foodborne illness regionally or nationally. In addition, data on sporadic cases can be used to gauge the overall incidence, severity, and distribution of foodborne disease in a population. Reported hospitalizations, deaths, and medical visits arising from foodborne disease can be used to estimate portions of the economic and social impacts. Additionally, selected outbreaks can be economically evaluated to determine their impact on the food industry. Data on the severity of some foodborne diseases (e.g., botulism, enterohemolytic *E. coli* O157:H7 infections of children, *Listeria monocytogenes* infections in infants) provide warnings that ought to justify surveillance [74]. Cost-benefit calculations can estimate the most cost effective control measure to implement.

Identification of emerging problems and stimulus to address them. When a new or poorly understood foodborne disease or agent that has the potential to cause disease is identified, active efforts to follow up on sporadic cases of the agent or to do a more in-depth investigation of outbreaks associated with the agent are appropriate. Such efforts can supply timely and useful information to define the problem and to develop control strategies. Additionally, recognition of new vehicles or faulty processes can stimulate regulatory agencies to take control actions and the food industry to take preventive actions. Trend and economic data provide information on increasing or decreasing impact on foodborne diseases and justification for their control and preventive actions. Furthermore, incomplete surveillance data can identify the need for improved investigative techniques and laboratory procedures.

Evaluation. Surveillance data provide information for evaluating the success or failure of programs. However, there are limitations on the quantity and quality of surveillance data, and these must be recognized to avoid misinterpretations of the data. Quantity relates to the occurrence of outbreaks, their recognition and investigation, and the commitment of the agencies concerned with surveillance. Quality depends primarily on the training and motivation of the investigators. The absence or low incidence of a particular foodborne disease may indicate a good food control system. For example, in developed countries today, botulism, generally, is a rare event. Mild cases of botulism, however, can be missed by a surveillance system. Sudden changes in trends need to be interpreted with caution; numbers of outbreaks may not have increased or decreased as much as the investigative or reporting system has changed.

Setting goals and priorities for food safety programs. Foodborne disease surveillance data include characteristics of the agents and situations that led to contamination of foods and to subsequent survival and possible proliferation or amplification of the contaminants. These data are essential for developing a rational approach to control activities and setting program priorities. When a problem becomes confirmed, gaps in existing regulations may become obvious. Laws can be enacted and regulations promulgated to guide the food industry toward safe practices. Such information can also be used to (a) teach students of environmental health, food technology, microbiology, toxicology, and nutrition; (b) train professional food regulatory officials, quality control personnel and food-industry workers; and (c) educate the public. Furthermore, a foodborne disease surveillance data bank can identify the most significant hazardous
practices. Priorities can, then, be set to prevent these hazardous practices rather than continuing traditional inspection activities that conform to regulations, but are of minor significance.

**TYPES OF FOODBORNE DISEASE SURVEILLANCE**

There are at least four types of foodborne disease surveillance: (a) reports of incidents by the agency responsible for disease surveillance, (b) laboratory isolations of foodborne pathogens from human beings, (c) sentinel community studies, and (d) hazard surveillance.

**Incident reports.** This type of surveillance relies on reports of investigations from local health departments, which are sent to state/provincial health departments. After review, these reports are submitted to the agency responsible for national disease surveillance. The extent and quality of data differ widely among states/provinces. Nevertheless, the reports are of actual incidents that have been investigated to varying extents. In some of the larger or more unusual events, local staffs are supported by state/provincial and/or national epidemiologists, laboratory services, and/or food regulatory officials. The reports are summarized by the national agency, usually a few years after occurrence of the incidents, and they are published as agency reports and/or journal articles.

This kind of surveillance is sometimes referred to as passive because local jurisdictions may or may not have systems in place to encourage reports and/or to investigate outbreaks. Furthermore, there is no obligation on states/provinces to send reports to the national agency. Although there may be active investigations in the community where the outbreak occurred, the reporting and interpretation of the data vary depending on the expertise available and priorities set by the administration. These data are often quite incomplete, but what is reported is what has been identified during investigations of incidents of foodborne illness. The long delay in providing these summaries diminishes their value. Nevertheless, their particular usefulness is in documenting and identifying trends over several years, provided that data collection over this interval is relatively consistent even though incomplete.

Surveillance becomes active when there is an ongoing search for incidents and outbreaks. This may involve calls to physicians, emergency rooms, laboratories, and/or health agencies, frequent review of logs and laboratory reports, and follow-up enquiries to determine the likely causes of the illnesses. Appropriate actions must be taken at all levels of surveillance.

**Laboratory isolations.** Laboratory reports of isolations of certain foodborne pathogens from human beings, and sometimes from animal reservoirs, are submitted to the agency responsible for disease surveillance. The information usually comes from laboratory isolations of enteric pathogens from persons ill enough to seek medical attention and of concern sufficient for the attending physician to obtain a clinical specimen and submit it to a laboratory. The extent of the surveillance depends entirely on physicians ordering clinical specimens and tests. Isolations from animals are frequently from animals being treated by veterinarians or may be sporadic, as a result of surveys of an etiologic agent of contemporary concern. In both situations, the data are skewed by sporadic surveys, outbreak-associated testing, duplicated isolations from the same individuals, testing limitations by some laboratories, and isolations from colonized rather than ill individuals. The mode of transmission is usually unknown. The disease may be waterborne, from contact with pets or domestic animals, or the result of person-to-person spread as well as foodborne.

Laboratory reports show trends in the morbidity of a disease over a long duration, but these trends are limited to the presence or absence of specific enteric pathogens (e.g., *Salmonella*, *Shigella*, *Campylobacter*). Other problems with laboratory surveillance data are (a) that marker typing is not always done because of the lack of ability or resources; (b) difficulty in maintaining supplies of high quality serotyping, phage typing and cell-assay reagents (48); and (c) many local laboratories are either unfamiliar with or do not use the newer molecular biology typing. Furthermore, many laboratories do not routinely culture *Campylobacter*, *E. coli* O157 and many other foodborne agents. Additionally, isolates of these pathogens are much more frequently made from sporadic cases than from persons or foods associated with outbreaks.

Timely and careful reviews of laboratory reports can identify (a) unusual increases in prevalence of isolates having a common epidemiologic marker, such as an uncommon serotype, or (b) clusters of cases associated by time, place, and person. Investigation of cases that form a cluster may identify common source foodborne outbreaks. Furthermore, isolates may be typed to give information on distribution. For example, after observation of increased isolations (29) of a relatively rare serotype, *Salmonella newbrunswick*, mostly from infants from 17 states, interviews revealed that the cases had ingested instantized dried milk that was processed in a particular plant (31). Field investigations revealed that the milk was heated without either thermostatic or time controls; buildup of caked powder was observed in regions in the instantizer that were inaccessible for cleaning; and weekly cleaning was done by a wet-cleaning method. *Salmonellae* were isolated from samples taken from the instantizer. Following a review of laboratory surveillance data, epidemiologic inquiry and investigation at the processing plant revealed the contributory factors, and appropriate control actions were taken.

Timely interviews of the cases associated with the laboratory isolations about their food consumption history may identify contaminated vehicles that would otherwise go undetected. Follow up of food histories of cases may detect a previously unknown source. For example, increases in human isolations of an unusual pathogen, such as *Salmonella eastbourne* (32), *Salmonella nina* (50), or *Salmonella napoli*, (42), over a short duration in a defined geographic area detected outbreaks involving chocolate products. Observations of pathogens being associated with specific foods, such as *Salmonella enteritidis* in shell eggs (79, 45), *L. monocytogenes* in cole slaw (73) and in soft cheese (55), and *Vibrio* spp. in shellfish (8) have helped recognize problems
sufficiently so that control measures can become more focused.

Sentinel site (case-control) studies. Sentinel community studies are sometimes undertaken for a specific pathogen or group of pathogens. Certain counties or metropolitan areas are selected where isolates of the pathogen being studies are reported, and the patients are interviewed as to foods commonly eaten. This is compared to food histories of matched controls in the sentinel communities. For the populations studied, these studies give accurate data on food preferences and the most complete data available on incidence of illness. Such studies are done only sporadically, however, and are time consuming and expensive. From the data collected, extrapolations are made as to the annual incidence of cases and deaths and high-risk foods for a region or country. The cases may or may not be foodborne, and the identified high-risk foods may or may not be actual vehicles; the data provide only bases for assumptions. Sentinel community studies have been used for listeriosis (41, 70, 75, 76), salmonellosis (30, 43, 65), and campylobacteriosis (9, 65).

Hazard surveillance. Hazard surveillance is the assessment of the occurrence of, distribution of, and secular trends in the prevalence of hazards (e.g., toxic chemical agents, physical agents, biomechanical stressors, and biologic agents) responsible for disease and injury (90). It has been used primarily with occupational diseases or environmental exposures. It identifies settings or individuals exposed to inappropriate or controllable levels of specific hazards that may lead to disease. Although not commonly practiced for foodborne diseases concerns, hazard surveillance would lend itself well to this purpose. Foodborne disease occurrence depends on factors (hazards) that affect contamination, survival, and/or proliferation of etiologic agents. Hazard surveillance is done, at least in part, during critical-item inspections of food establishments (2, 20), and it is the main focus of the hazard analysis component of the hazard analysis critical control point (HACCP) approach (16, 18, 52). These investigations focus on factors that have been shown to contribute to foodborne illness (11, 14, 33, 72, 83, 91) rather than on disease occurrences. A benefit of this type of surveillance is that items under surveillance are also those to be targeted for primary prevention. These events occur much more frequently than reported disease outbreaks and can be the focus of inspections, surveys or hazard analyses, and monitoring of the hazards can be done during these activities. This approach anticipates disease outcomes and does not just react to them as do the other forms of surveillance.

Other sources of data. There are other sources of data that indirectly reflect on the incidence of foodborne diseases. These include (a) autopsy data on exposure to Trichinella (94), (b) antibody surveys on exposure to Toxoplasma (78), (c) surveys of pathogen carriage in feces (1), (d) studies of groups of persons with identified pathogens (59, 77), (e) estimates of foodborne disease from analysis of health surveys or cases of diarrheal disease (40), (f) data on the prevalence of isolates of pathogens from foods or from food-source animals (19), (g) literature searches on likelihood of reporting (25), (h) hospital discharge surveys (77), (i) case-control studies of sporadic cases (63), and (j) cohort studies (57). Special studies have also been made of hemolytic uremic syndrome (53, 59, 67) and verotoxigenic E. coli (24, 29, 68) which may be related to foodborne transmission. In all of these studies and surveys (except those on trichinelllosis, which is always foodborne), the percentage of infected or ill persons resulting from the ingestion of food is unknown and can only be estimated. Sources of surveillance data are summarized in various texts (36, 89).

SURVEILLANCE NETWORKS

A foodborne disease surveillance network serves as the foundation for sharing information about foodborne illness with those who report data to the network and with those who have a vital interest in the subject. The network should have established policies and procedures and a person in charge at the local, regional, state/provincial and national (and under some circumstances, international) levels. Policies should cite statutory authority for the surveillance network. They should clearly state that high priority should be given to establishing and maintaining the network and to responding to reports of alleged foodborne illness. They should also specify timely notification of the existence of outbreaks to higher administrative levels and the necessity for timely submission of complete final reports. The policies should define the roles played by the various agencies involved. Procedures should be developed at each organizational level.

There must be administrative commitment for a surveillance network at all levels. This includes provision of a qualified and trained staff and supplies and equipment for (a) collecting and testing clinical specimens, food, and environmental samples, (b) measuring temperatures of foods during processing and preparation, and (c) analyzing data. The supervisor of the program must ensure that investigation reports are timely, thorough, and complete.

Local levels. Typically, local health departments are responsible for establishing contacts and receiving notification of illness. These departments usually identify outbreaks and staff the investigations. Clinical specimens may be tested by local laboratories, or they may be referred to regional, state/provincial, or national laboratories as the facilities and need for specialized reference services dictate. Local offices should notify state/provincial surveillance offices when the outbreak is first identified and cooperate with these agencies for a coordinated response. If local staff have sufficient information to warrant such action, they should embargo or otherwise stop sales and issue alerts to prevent further cases of illness if additional contaminated food is still in distribution. The local offices must provide training to secretarial/clerical staff on the manner for responding to persons making complaints of foodborne illness and to log complaints and alerts. They should conduct periodic staff seminars/coordination meetings regarding foodborne disease surveillance for representatives from appropriate units in their departments. Outbreak investigations, as opposed to recording of notifiable diseases or laboratory
isolations of enteric pathogens, are the main means of alerting public health authorities to new problems, e.g., botulism from baked potatoes (58) and from garlic in oil (80), salmonellosis from melons (39) and tomatoes (47), S. enteritidis infections from eggs (79), and bloody diarrhea and hemolytic uremic syndrome from undercooked hamburgers (6, 34, 66).

A local health office may receive notification of foodborne illnesses from many sources: physicians who have diagnosed the illness, laboratories that have identified foodborne agents in specimens from patients, health care facilities that have treated patients, the victims themselves, or family members of the victims. Notification by local health providers and laboratories can be enhanced by meetings with local medical groups, emergency room staff, and infection control practitioners. Regular contact with health care providers and feedback through newsletters can stimulate continued cooperation. Notification from victims can be enhanced by raising public awareness with public service announcements and brochures. Listing a 24-hour foodborne-disease-reporting telephone number in the directory under local/regional health department entries draws attention to the department to which such illnesses are reported and may stimulate reporting.

High priority must be given to immediate response when an outbreak is reported. Delays in response or a limited response reduces the chance that the investigation will identify vehicles, reservoirs, and contributory factors. Small family or foodservice-related outbreaks are usually over by the time an investigation begins. This does not mean, however, that investigation and documentation have no value. The outbreaks may be due to commercial food still in distribution, and action must be taken rapidly to stop sales and/or to recall the contaminated product. Additionally, the information learned can be used to educate food-industry personnel involved and the public about the risks associated with food preparation in these settings.

State/provincial levels. State/provincial foodborne disease surveillance agencies (a) monitor and sometimes coordinate ongoing large-scale investigations, (b) provide consultation, back-up staff, and laboratory reference services (c) coordinate response with other governmental agencies and industry within their jurisdictions, (d) issue public alerts, (e) initiate recalls or embargoes, and (f) in some cases, conduct the investigations. These agencies should take the lead in developing and providing training for the professional staffs of both state and local agencies who conduct or otherwise support foodborne disease investigations. Laboratory reports of enteric pathogens may reveal clusters of cases that may have a common origin. These can be followed up to see if there are any food associations that indicate a possible source of infection, either at the local level or by other agencies if a widespread distribution is suspected.

A record keeping system should be established to track ongoing investigations and specimen analysis and to log and review final reports (44). A copy of the final reports should be forwarded to the national agency responsible for foodborne disease surveillance. State/provincial surveillance agencies should analyze and summarize their data on an annual, multiyear or special purpose basis to identify trends and evaluate programs. Data based on this information should be used to justify amending regulations.

National level. Data from final reports should be entered into a computer database for collation and trend analysis. These should be interpreted and distributed back to state/provincial and local jurisdictions in a timely fashion. An outbreak that has the public attention, such as the E. coli O157:H7 incident in the western states of the U.S. (6) or the domoic acid episode involving contaminated mussels in eastern Canada (69, 85), affect policy changes that result in better control of hazards of the food supply. A comprehensive and accessible data bank (including information on foodborne disease outbreaks and surveillance summaries and articles on pathogen characteristics that may affect prevention and control and antibiotic resistance) should be done to show the chain of transmission of etiologic agents. Local and state/provincial surveillance activities can be strengthened by training personnel and supplying surveillance guidelines and, upon request, assisting in investigations. Coordination should be established with the mass media to ensure timely alerts about continuing outbreaks, epidemics and preventive measures, and to assist in preparing news releases, but also to react to misleading and incomplete information by the media. Grants should be provided for applied research relating to surveillance and rapid diagnosis of foodborne diseases and to control of those diseases of contemporary importance. Sentinel surveillance networks are best established at the national level. National surveillance centers should also participate in intracontinental surveillance center data banks, so as to counter the spread of such diseases as cholera, salmonellosis, and others that will emerge as pandemics in the future.

International level. International reporting is done in Europe (51). Each participating country (a) describes its official reporting system, (b) specifies diseases that are obligated to be reported in that country, (c) submits data on causative agents, foods involved, places of outbreaks, and contributory factors based on reports of laboratories involved in the investigations, (d) reviews information coming from special surveys, and (e) gives prospective comments on the reporting system. The objectives are to identify causes of foodborne diseases in the region, distribute the gathered and collated information to those concerned, and cooperate with national authorities in an effort to strengthen the prevention and control of foodborne diseases. Over 30 countries, including some outside Europe (e.g., Israel), participate in the program. There is considerable variation in reports from different countries because investigations are carried out by various agencies according to traditional development of public health, veterinary services, or environmental protection services. Hence, exact comparisons of national figures are not possible presently, and differences in morbidity may find their explanation in the different methods of reporting. Nevertheless, useful information on the foodborne disease situation is obtained (86). These data are summarized in reports every few years. Additionally, newsletters that are published about four times a year are sent to 1,300 interested agencies, institutions, and scientists.
Recently, the World Health Organization’s Regional Office for the Americas issued a manual on foodborne surveillance (37). The object of the manual is to disseminate information on the impact of foodborne diseases in the Americas. The office promotes and supports development and strengthening of national surveillance systems. Plans are to set up a laboratory network to support investigations.

SURVEILLANCE AIDS

Computer software can assist investigation and management of the information submitted to surveillance networks. “Epi Tracker” (62) is a program that can be used by local public health agencies to track and link sporadic case reports and illness complaints to possible common exposures. It is based on the investigative approach called for in Procedures to investigate foodborne illness (17). It can analyze case reports and outbreak trends in a community and can be used by program management to redirect the emphasis of food safety programs based on current epidemiologic trends. It is available on the Electronic Inspection System of the U.S. Food and Drug Administration (38).

“Epi Info” (35) is a program that assists in developing an interview questionnaire; after entry of the interview data, it automatically prepares epidemic curves, food-specific attack rate tables, statistical analyses, and summaries of signs, symptoms, incubation periods and duration. A feature makes statistical calculations. The database program enables a surveillance system to compile the information for tens or hundreds of outbreak reports to be used for trend analysis. It is used worldwide and is available commercially (see Dean et al. (35) for the listing of the source). Data files from Epi Tracker can be imported into Epi Info.

“Foodborne Disease Surveillance” (44) is a menu-driven program developed by the New York State Department of Health and built on a relational database that can be used to track ongoing outbreak investigations and the submission of investigation final reports. (It is available from the Bureau of Community Sanitation and Food Protection of that department.) The program can automatically compile ten different summary tables from completed investigative data, make status reports, and generate line listings of ongoing investigations. The program also allows the user to design and print customized tables of surveillance data.

Electronic reporting programs enable state/provincial and national surveillance networks to collect information over a modem or on a disk submitted by mail, thereby, facilitating data collection and analysis. The Centers for Disease Control and Prevention in cooperation with the Association of State and Territorial Public Health Laboratory Directors in the U.S. have developed a laboratory information system (PHILIS) (5, 61). It is a PC-based relational database electronic reporting system. Data entry screens are created locally and distributed to all reporting sites (state and federal) electronically, and data are input and reported within hours. The newest version can accommodate data for epidemiologic, laboratory, survey, and case-control studies. Features include user-defined modules, report writing, electronic feedback to reporting sites, internal electronic communications software, pyramid reporting logic, system designed security features, and the ability to depict data geographically. Additionally, field staff can customize for special needs. Campylobacter, E. coli O157:H7, Salmonella and Shigella are included in the program. Another system, laboratory information tracking system (LITS), contains data from all laboratories that performed tests on a specimen. Electronic reporting of all isolations of certain pathogens to a central reporting agency greatly enhances the timeliness and value of this system. E-mail has been useful for questioning delegates returning from conferences to follow up on a suspected foodborne salmonellosis outbreak. Most responses by fax to the request for information were received within 8 d of the e-mail transmission (60). This form of communication may prove to be particularly useful where widely dispersed foodborne disease outbreaks are suspected.

A program, INC, developed by the WHO Surveillance Programme for Control of Foodborne Infections and Intoxications in Europe is based on Epi Info (93). It is used for entering incident reports from various countries. It contains code categories, allowing selection of entries on causative agents, foods, places where food was contaminated, places where foods were acquired and eaten, and contributing factors. Graphs and tables from this data can be generated from Epi Info.

INCIDENT REPORTS

Data on individual incidents are ordinarily summarized in a report that is sent to agencies responsible for foodborne disease surveillance at state/provincial and national levels. Information summarized usually includes (a) location of the event, (b) clinical data, (c) epidemiologic data, (d) laboratory findings, and (e) results of on-site (environmental) investigations (Table I.1). (For more details see Form K (17), appropriate discussion in the IAMFES foodborne disease investigation manual (21), and Table III.8 (21) and discussion (in Part IV of this Series) (87). Narrative reports giving interpretations of the findings with accompanying investigative forms, tables, and graphs should be attached to the reports. The Foodborne Disease Reporting Centre, Health Protection Branch, Health Canada requests that data be submitted on the IAMFES form. The CDC and the WHO European surveillance of foodborne disease network use different, but similar, forms (27, 51).

These reports present a standardized format for reporting investigation findings. The individual reports become the building blocks for developing a surveillance data bank on which trends can be observed. Without them, effective foodborne disease surveillance could not exist. These reports, however, are frequently deficient in one or more areas. Deficiencies include (a) late notification, (b) unavailability of clinical specimens and/or food samples, (c) unsuitability of laboratories or methods to identify agents, (d) insufficient resources or trained staff to conduct investigations, (e) lack of cooperation from operators and/or those persons affected, and (f) failure of investigators to write a final report or to complete report forms. Additionally, a history of lack of, or
TABLE I. Incidence data

<table>
<thead>
<tr>
<th>Category</th>
<th>Data needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Community, State/Province, Place foods acquired</td>
</tr>
<tr>
<td>Clinical data</td>
<td>Type of illness, Date of onset of first case, Major symptoms, Duration (shortest, longest, median), Incubation period (shortest, longest, median)</td>
</tr>
<tr>
<td>Number ill</td>
<td></td>
</tr>
<tr>
<td>Number at risk</td>
<td></td>
</tr>
<tr>
<td>Number interview</td>
<td></td>
</tr>
<tr>
<td>Number hospitalized</td>
<td></td>
</tr>
<tr>
<td>Number of deaths</td>
<td></td>
</tr>
<tr>
<td>Epidemiologic data</td>
<td>Epidemic curve (time of onset of each case, not incubation period), Attack rate table indicating the vehicle and, when applicable, significant ingredients, with calculations of associations and probability, Other tables and graphs developed as a result of the investigation, Associations and probability calculations</td>
</tr>
<tr>
<td>Laboratory data</td>
<td>Isolation of etiologic agents from specimens from patients and samples from foods, equipment, and environment</td>
</tr>
<tr>
<td>Environmental</td>
<td>Final place foods mishandled (contaminated, if data applicable, and where survival and/or growth occurred), Method of processing/preparing food</td>
</tr>
</tbody>
</table>

Individual foodborne disease outbreak reports should be carefully reviewed within agencies responsible for compiling and analyzing data to ensure that the findings and conclusions were arrived at through appropriate procedures (12, 13, 17, 64). When questions about the data are identified, original investigators should be contacted to resolve those questions. In some instances, there will be insufficient information to classify an individual outbreak as foodborne. When inadequately completed reports are received, the review agency should provide training, technical consultation, or other needed support to the investigating agency to ensure better quality investigations and final reports in the future.

Investigations are made to establish causation. Hypotheses are formed and tested to associate causal factors with disease occurrence. This is done by deciding whether one or more factor(s) could possibly be the cause (or contribute to the occurrence) of foodborne illness. Associations can, however, be coincidental or indirect rather than causal. Coincidental associations result from chance occurrences or biases in the study method. Indirect associations are related to some undetected, underlying condition. Also, association can be inverse to the cause and can even have a protective effect, such as choosing one food in preference to the contaminated one. Criteria for assessing causation based upon those presented by Hill (49), but modified to relate to foodborne situations, are as follows:

Strength of association. An association between the supposed cause and the effect provides evidence of causation. The stronger the association, the greater the chances of a causal relationship. For this criterion to be significant, significantly higher rates of disease must be observed in groups exposed to a vehicle, factor, or environment that contains the etiologic agent than are observed in groups without such exposure. Ideally, for example, everyone who ate a specific food becomes ill and everyone who did not eat the food remains well. This is seldom the case with interview data, but rates between the two groups ought to have a statistically significant difference, and the larger the difference, the higher the probability of causation. These associations, however, are difficult to attain for many small outbreaks.

Consistency of occurrence or association. The association between the suspected cause and the outcome should be seen in numerous outbreaks or studies, ideally conducted by different investigators or teams in different settings and under different circumstances. The same biases, however, might be repeated by the different investigators or influenced by similar circumstances. The larger the number of outbreak investigations or studies that demonstrate a relationship, the more consistent the association. Furthermore, there should be a lack of alternative rational explanations.

Specificity of association. Ideally, the same cause should lead only to one outcome, and that outcome should result from a single cause. The same manifestation should occur when the agent infects different persons or when a substance is ingested by different persons. Exceptions are that (a) some agents can cause more than one syndrome, (b) some factors must act cumulatively or subsequently to other factors before an effect occurs, (c) some vehicles convey several etiologic agents that cause different syndromes, and (d) sometimes different causal factors exist for the same syndrome. Specificity also includes finding the same species, serotype, phage type or other epidemiologic marker from the source, reservoir, food, and ill person. Specificity of association strengthens the case for causality, but a lack of specificity does not necessarily weaken it.

Temporal association. At least one causal factor must precede the onset of illness. The duration between ingestion of the contaminated food and onset of illness must
**TABLE 1.2. Line listings of incidents of foodborne diseases**

<table>
<thead>
<tr>
<th>Inc. no.</th>
<th>Etiology/disease</th>
<th>Onset date&lt;sup&gt;a&lt;/sup&gt; (1st case)</th>
<th>Suspected food acquired from</th>
<th>Clinical data</th>
<th>Laboratory data&lt;sup&gt;d&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Locality (insert codes)</td>
<td>Establishment (insert codes)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>No. ill&lt;sup&gt;e&lt;/sup&gt;</td>
<td>No. interviewed</td>
<td>No. at risk&lt;sup&gt;f&lt;/sup&gt;</td>
<td>Incubation period (h)</td>
</tr>
<tr>
<td></td>
<td></td>
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</table>

* Incident number; numbered sequentially.

* Etiology: Listing by category of agent, alphabetically by etiologic agent, by date, or disease, listed alphabetically by disease category.

* Onset: The dates given should be as accurately as can be ascertained. When data are available, the range between the dates of the first and last case is given.

* Locality and establishment: Community where incidents occurred; places from which food was acquired or eaten; see Table 1.5 for codes (22).

* Estimated, if not known precisely.

* Clinical data: Indicate signs and symptoms by letter; C = cramps/abdominal pain; D = diarrhea, F = fever, H = headache, N = nausea, P = prostration, V = vomiting; and insert other letters with explanation for other signs and symptoms in footnotes.

* Laboratory data: X should be put below the appropriate letter which indicates isolations from . . . C = case; V = vehicle; W = food workers.

be consistent with an appropriate incubation or latency period. This is usually obvious with foodborne diseases having short incubation periods, but it is often difficult to establish for diseases having long incubation periods (up to 6 weeks). Early reported cases in an epidemic are more likely to be associated with a common source. Subsequent cases may be caused by secondary transmission from foods that were cross-contaminated from the original sources or by persons infected from the first episode.

**Biological gradient.** More exposure or a larger dose leads to more disease. The clinical disease might be more severe, incubation periods might be shorter, and incidence or rates of disease might be higher when large doses of an infectious or toxigenic agent are ingested or otherwise acquired. Conversely, minimal effect, longer incubation periods, and a low incidence of disease are observed with low doses of the agent. There may be an amount (or threshold) of the agent below which there are no adverse effects and an upper limit above which further increases do not lead to a greater effect. For example, death may be a certainty above a certain concentration of a toxin, but below a threshold level, there may be a dose-response relationship with the severity of illness. Individual differences in susceptibility of hosts and in virulence of species and strains, however, will cause variation in effects with dosage.

**Biological plausibility.** The association must make sense in the context of existing knowledge of biology or toxicology. The hypothesis should include the source and mode of contamination, whether the agent survived any potentially lethal treatment, and whether the agent increased during food production, processing, storage, or preparation. Lack of biological plausibility, however, may reflect incomplete knowledge about the agent, host, and contributory circumstances. The number of different hypotheses formulated to explain a given biologic phenomenon is generally inversely proportional to available knowledge.

**Coherence.** Interpretation of the data should not seriously conflict with generally known facts of the natural history and biology of the disease. Laboratory evidence can strengthen a hypothesis and may determine the actual causative agent, but the lack of such evidence cannot nullify the epidemiologic observations.

**Experimental evidence.** Experiments may take the form of laboratory (e.g., challenge) tests, randomized trials,

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**TABLE 1.2. (Continued)**

<table>
<thead>
<tr>
<th>Inc. no.</th>
<th>Food group</th>
<th>Subgroup/type</th>
<th>Process</th>
<th>Specific food</th>
<th>Place of mishandling&lt;sup&gt;i&lt;/sup&gt; (insert codes)</th>
<th>Method of processing or preparation&lt;sup&gt;j&lt;/sup&gt; (insert code)</th>
<th>Contributory factors&lt;sup&gt;k&lt;/sup&gt; (insert codes)</th>
<th>Comments&lt;sup&gt;l&lt;/sup&gt;</th>
</tr>
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<tbody>
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</table>

* Incident number: numbered sequentially, this number must agree with the corresponding line in the first part of the table.

* Vehicle: the food implicated in the incident by category(ies) and specific item or significant ingredient.

* See Table III.5 in Part II for code for place of mishandling (21).

* See Table III.7 for codes for method of processing/preparation (21).

* See text in Part III and Table III.8 for codes for contributory factors (21).

* Comments should include all other relevant data, such as time/temperature abuse of the implicated vehicle, information on a change in manufacturing practice, bacterial counts, and other bits of information that may be useful.
animal models, experiments in nature, or interventions in which a preventive action is taken. Results that decrease or prevent subsequent illnesses strengthen the case for causation. It is extremely difficult, expensive, or unethical to do dose-response studies (e.g., human volunteer ingestion of contaminated food or pathogens) that would yield proof often desired by investigators. Also, healthy adults would have to be selected, a practice that would not show the effects for aged or immunocompromised persons. Preventive actions can be taken, however, and the prevalence of contamination or incidence of illness monitored.

Analogy. Analogy of the current situation can sometimes be made to previous situations that had causal associations. This, however, is the weakest form of evidence.

Summary. Meeting these criteria do not prove causation; they only strengthen the case for it. The more criteria that are met, however, the more strength is given to an association. Each outbreak should be subjected to this sort of review before classifying it into the various categories of surveillance data. Such a review would also be useful when comparing surveillance data of different intervals and places.

LINE LISTINGS

Highlights of individual reports are tabulated (in computers or by hand) as line listings that are the direct sources of surveillance data. Data for each outbreak are usually grouped by time (data and year), place (community), and person (number ill and number at risk). The confirmed or suspected food is also listed, sometimes with the place that the food was acquired, eaten, or mishandled. Additionally, information may be summarized on predominant symptoms, incubation period, duration of illness, and factors contributing to outbreaks. Line listings present incidents in a uniform way and ease tabulation, collation, and summarization of data. The listings keep data in one place so that they can be easily retrieved. They lend themselves to computerization. Annual highlights of reports are listed together, obviating the need for repetitive review of individual reports. To ease summarization and computerization, foods, places, methods of processing and preparing, and contributory factors are often grouped into categories that are too general to be of much value in determining causative factors. Entries are often recorded as unknown because the reports, forms from which the data are taken are incomplete or unconfirmed; this limitation can be readily seen from blank spaces in the listing. (See Table 1.2 for entries that can be tabulated for each incident.) Annual (or other intervals) summarization can be derived from the cumulative line listing through sorting by categories (e.g., etiologic agents, vehicle, location), which can focus on the most important components of the incidents. This listing is coordinated with the data summarized in the tables to be presented in the other parts of this series.

CONCLUSIONS

Many recent reports on the incidence of foodborne disease point to major difficulties in assessing the current status of the problem and providing early warning of emerging problems. These difficulties are compounded when attempts are made to compare data from different jurisdictions. Surveillance and reporting practices vary widely within and between countries leading to widely different assessments of the incidence and significance of foodborne disease in a particular community, region, or nation. Furthermore, the misuse of this information (e.g., as nontariff trade barriers or by one industry sector against another (e.g., red meat versus poultry versus seafood), obscures the common goal of providing a safe and wholesome food supply.

The need for a surveillance system has been established, but committed and ongoing resources are required to provide consistent and reliable data for effective analysis. Furthermore, data must be collated, interpreted intelligently, and presented in an organized fashion. The data, then, must be used to improve food safety, which is the benefit of an effective surveillance program, as discussed in the other parts of this series (21, 22, 87).

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