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SURVEILLANCE FOR THE EFFECTS OF WORKPLACE EXPOSURE[1]

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INTRODUCTION

Surveillance of workers for the effects of workplace exposure can be considered as consisting of three major but overlapping areas. Although many definitions of biologic monitoring and screening exist (1–5, 53), we define *biologic monitoring* as the testing of a biologic sample such as blood or urine for the presence of an intoxicant or its metabolite; and we define *medical screening* as (*a*) the examination of the asymptomatic worker for early signs or symptoms of disease resultant from workplace exposure, or (*b*) the examination of workers for conditions that place them at extraordinary risk to themselves or co-workers during routine job conditions or exposures. Surveillance of workers is the collection, assimilation, and use of biologic monitoring, medical screening or other health data for developing strategies for the prevention of disease. Biologic monitoring, medical screening, and surveillance are three components in a continuum of preventive practices (6, 7, 50, 51) useful in the preservation of occupational safety and health.

THE CONTINUUM OF PREVENTION

There are three levels of prevention of disease: primary, secondary, and tertiary. *Primary prevention* connotes the exclusion, cessation, or limitation of

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exposure so that the disease process is not initiated. *Secondary prevention* is the detection of the disease process in an early stage before the process is irreversable or when the disease is more easily treatable than if discovered later. Treatment at this early stage of the disease process should be differentiated from *tertiary prevention,* which is the appropriate treatment of disease at the time of its usual rather than early diagnosis. Clearly, primary prevention is preferable to secondary prevention.

Continuum of Prevention
- Primary:
  - Premarket testing
  - Substitution/elimination
  - Engineering controls
  - Personal protective devices
  - Environmental monitoring
  - Biological monitoring
- Secondary:
  - Medical screening
- Teritiary:
  - Clinical care
  - Rehabilitation

In the continuum of prevention several activities, mostly in the realm of toxicology and industrial hygiene, fall into the category of primary prevention. Ideally, agents would be tested in animals for toxicity before entering commerce. The Toxic Substances Control Act (8) (TSCA) mandates premarket toxicological testing in certain cases. In 1977, 48,523 agents already in commerce were listed on the TSCA Inventory. The National Research Council has recently estimated that no toxicity information is available for nearly 80% of these chemicals in commerce (68).

Substitution of less hazardous agents is also an example of primary prevention, as is the use of engineering controls to limit workplace exposure. The use of personal protective devices such as gloves, masks, and gowns to further separate the worker from his environment are also examples of primary prevention. Recent requirements for labeling of workplace hazards mandated both at the federal (9) and at the local level can be viewed as an extension of worker education and will probably contribute to primary prevention.

Environmental monitoring is useful in ensuring that these preventive measures are effective in limiting exposure. Environmental monitoring is not a substitute for the earlier and preferable primary preventive measures, but rather a method of keeping watch on the workplace to ensure that these measures are used and are effective.

Limited opportunities for primary preventions occur at the level of the practicioner-patient interaction. Through the preplacement examination, (56–59) employees can be placed in jobs in which their physical or other limitations or the demands of the job do not place them or their co-workers at excess risk. Farther along the continuum, biologic monitoring straddles primary and secondary prevention. On the one hand, measurement of the worker for absorption of an intoxicant or its metabolite is a better indicator of exposure (or worse when one considers that the intoxicant is already absorbed) than is environmental monitoring. For example, agents of low vapor pressure that are not detected in air samples can still be absorbed through the skin. Also, the permissible level of workplace ambient exposure may not accurately predict the level of biologic absorption. On the other hand, biologic monitoring technically should be considered secondary prevention when it measures not the intoxicant (such as lead) but altered physiological response (such as elevated protoporphyrin). Purists would argue that this is an example of screening, and not biologic monitoring.

Medical screening is more clearly secondary prevention. One goal of medical screening for early signs or symptoms of disease is to detect the disease process early in its course, when it is reversible or more easily treatable, such as the early diagnosis of lead poisoning. A second goal of medical screening is to detect disease at levels of exposure assumed to be safe, such as the continuing surveillance of asbestos-exposed workers as "safe" levels have been lowered progressively. A third goal is to detect disease suspected from toxicological studies in animals, but not previously documented in workers, such as monitoring workers exposed to methylene-bis-(2-chloroaniline) (MBOCA), an animal bladder carcinogen, for abnormal cytology suggestive of bladder cancer. The periodic medical examination used commonly in industry is an example of medical screening. Detection of disease early in its course is not preferable to more primary measures of prevention. It is, however, more preferable to treating disease at its usual time of detection, often when the disease is well advanced. Advanced or symptomatic disease is often less amenable to definitive cure. By detecting cases earlier we gain an opportunity to reduce exposures for other workers similarly exposed.

Surveillance spans this continuum of prevention. It is a technique that can transform how data is used. Data, whether they be from environmental or biologic monitoring, screening, medical claims, death benefits, etc, can be treated as isolated information essentially collected for the benefit of the individual and systematically filed in that individual's chart or folder. Alternately, aggregate data from groups of individuals in one workplace, one industry or occupation can be collected, assimilated, and used as the basis for inference to identify opportunities for prevention. Surveillance contributes to the intelligence on which public health workers plan their interventions, yet it is startling that not one Federal Occupational Safety and Health Administration regulation requires the surveillance of biologic monitoring and screening data that is required to be generated for workers covered by a series of OSHA regulations. In addition, only a handful of the states that routinely conduct communicable disease surveillance conduct any occupational disease surveillance.

The continuum of prevention is the theoretical construct. At a practical level we discern a growing interest in biologic monitoring, screening, and surveillance. There appear to be at least four reasons for the increasing interest in biologic monitoring, medical screening, and surveillance:

1. The history of occupational safety and health is marked by episodes of occupational disease that represent failures of the preventive continuum. For example, although it was previously known that dibromochloro-propane (DBCP) caused testicular atrophy in animals (10), it was not until a cluster of oligospermia was noted in workers who formulated pesticides that effective preventive action was taken (11). This and similar episodes have pushed the occupational health community toward greater acceptance of regulation of agents based on animal studies. Such episodes also demonstrate that biologic monitoring and screening techniques may be valuable as an early warning that adverse effects are occurring. This information is valuable when an agent is feared toxic on the basis of animal studies, but exposure has not been controlled by primary preventive measures.

2. Recent advances of understanding of genetics at a cellular level have resulted in the discussion of the use of techniques of biological monitoring (12, 26). Several enzymatic abnormalities have been delineated, such as enzyme difficiencies of glucose-6-phosphate-dehydrogenase and alpha-1-antitirypsin, that suggest that some individuals, based on genetic characteristics, may be at an increased risk of disease from chemical exposure. Because these abnormalities are apparently more common in certain racial and other subpopulations, the exclusion of those workers with enzyme deficiencies may be a form of discrimination (13, 14). This situation is even more difficult because data demonstrating risk to workers with these defects is scant.

Even more problematic is our ability to detect alterations in genetic material that result from workplace exposure, as in tests for chromosomal aberrations (15), sister chromatid exchange (15), and aberrations of hemoglobin molecules by alkylating agents (17), such as ethylene oxide, or adduct formations (18) of DNA itself. Although these tests can be viewed as biologic markers of exposure, their prognostic significance is unclear. Essentially, interest in these newer techniques has focused attention on the efficacy, legality (14), ethics (52, 55), and politics of genetic testing (26), as well as on more commonly used techniques as well.

3. A marked growth in computer systems has allowed the collection, storage, and analysis of health, environmental and other data that would otherwise be filed in individual charts. This computerization of data provides an opportunity for managers to assess the value and use of each datum collected. Several commercial computer systems are available that can accept and tabulate information on industrial hygiene and medical and personnel records (19).

4. There is some concern about the effectiveness of these measures. Medical screening evolved under the assumption that periodic examinations were effective in improving health. Medical screening was used by the armed forces in World War I to ensure a healthy military force (5, 20). In the post war era, the efficacy of periodic examination was assumed by industry, particularly the insurance industry, and screening examinations were instituted both upon getting a job and in obtaining insurance.

Medical screening, like many other medical or surgical interventions, received scant critical or systematic evaluation of effectiveness until after World War II. Some would mark a turning point in the interest in evaluation of medical practices to the growth of multiphasic, automated testing after World War II (5). Cochrane (21, 54), one pioneer, called for the evaluation of the effectiveness of medical procedures; recently this critical evaluation has focused on the periodic health exam. Both in Canada (22) and the United States (23) there have been recommendations for a reconstruction of the periodic health exam, better directed at the risk factors associated with the age, sex, personal habits, and occupational risks of the patient. Government agencies require or recommend medical screening for over 400 agents (24). The volume of these recommendations and requirements, along with proposals for new recommendations, have forced a reassessment of the nature of medical screening.

Current Use of Medical Screening and Biological Monitoring

Our knowledge of the prevalence of biologic monitoring and medical screening is limited. In 1972–1974, a multi-staged probability sample of 5000 of the approximately 5 million industrial workplaces covered by the OSHA was conducted by the National Institute for Occupational Safety and Health. (Important exceptions were agriculture and mining.) That survey, known as the National Occupational Hazard Survey (NOHS) (25) provides a profile of biological monitoring and medical screening practices at the dawn of the OSHA era. NOHS results show that of a projected 38 million workers, 48% had a preplacement exam and 34% a periodic examination. The specific exams do not seem to reflect the potential hazards observed in the workplaces in the course of the survey. For instance, 28% of workers exposed to dust had chest X-rays as compared to 25% overall in industry.

Factors other than hazards seem to determine the prevalence of screening. At the time of NOHS the prevalence and type of screening programs in industry were directly related to the size of the plant: 12% of workers in companies with less than 100 employees had periodic exams, 29% in companies with 100–499, and 65% in companies with more than 500 employees. The presence of union and the availability of industrial hygiene services were independent predictors. NOHS data depict the situation as it existed in the 1970s. How this situation has changed in this past decade will be evident when data for the repeat survey, the National Occupational Exposure Survey (NOES) becomes available starting in 1985.

More current information is available on the use of newer genetic monitoring methods (26). In 1982, the Office of Technology Assessment surveyed the 500 largest industrial companies, the 50 largest private utilities, and the presidents of 11 major unions concerning the current, past, and future uses of genetic screening tests: 1.6% currently use such tests, 4.6% had used them at sometime in the past 12 years, and 1.1% planned to assess their future use.

Types of Screening

Medical screening and biological monitoring tests can be offered in at least three contexts (4). Case-finding describes the situation in which workers seeking medical care for an unrelated problem (e.g. laceration) are offered a screening test (blood pressure). Alternately, in a "screening program" the availability of a test can be announced and made available to any worker who consequently appears at the medical office or even a booth at a "health fair." In a screening survey, the investigator actively seeks a high participation rate of a probability sample in order to characterize accurately the distribution of results in the target population of workers. The employees of plants also have been proposed as target populations for "screening programs" for diseases not directly related to occupational exposure (27). Occupational health programs may play a substantial role in screening for diseases other than those of occupational etiology, such as hypertension, glaucoma, etc, but this motive for screening is not the subject of this brief paper.

Precepts for Screening

Considerable theoretical attention has been focused on medical screening as practiced in the community. Precepts have been delineated by Wilson & Junger (3) and further elaborated by Sackett & Holland (4) and Cole & Morrison (28). Many of these precepts are not transferable directly from the community to the workplace. For instance, in the community, diseases that are sought must be treatable, but in the workplace even untreatable conditions can be sentinel diseases that point to the failure of the preceding steps in the continuum of prevention (29). The precepts suggested by Wilson & Junger are presented in parallel with revised precepts for screening for the effects of occupational exposure (Table 1). A fuller treatment of these precepts can be found in (30).

Techniques for Screening

A full discussion of the techniques for biologic monitoring and medical screening is beyond the scope of this presentation. Proceedings of a joint NIOSH/NCI/EPA Conference on "Biologic Monitoring and Screening for the Effects of the Workplace Exposures" covers many methods (30a). One recent text describes methods for analysis for biologic monitoring (31). Another text (32) reviews results of field trials with these methods as well. Some of the methods for biologic monitoring may not be validated for levels of exposure to be expected in contemporary occupational environments. For many tests of biologic monitoring, a relationship can be drawn between biologic level and exposure, but not between biologic level and health effect. A series of reviews in the *Annual Review of Public Health* (33) describe in depth screening and monitoring for a few agents (cadmium, mercury, PCBs) and offers an introduction to newer techniques for assessing DNA adducts (18) and hemoglobin alkylation (17).

Techniques for Surveillance

Langmuir's (34) account of the use (and misuse) of the word "surveillance" as a descriptor of a public health activity provides a good starting point for reviewing the evolution of occupationally related disease surveillance. In the period from 1850 to 1950, due mainly to the influence of Farr, surveillance was used to mean the ". . . specific, but limited function of watching contacts of certain serious diseases such as plague, smallpox, typhus, and syphilis" (34). By the end of World War II, the epidemiologic techniques developed by the Office of Malaria Control in War Areas (MCWA) and its successor, now the Centers for Disease Control (CDC), shifted the target of surveillance from people to diseases, e.g. polio and influenza (35).

In 1966, primarily through global efforts to erradicate smallpox, "surveillance became synonymous with containment including active vaccination of large numbers of people" (36). An added emphasis for surveillance of disease emerged in 1976 when Rutstein provided a list of sentinel health events that could be used to evaluate the quality of medical care (37). Working with Rutstein, the staff of the National Institute for Occupational Safety and Health (NIOSH) has adapted this concept of sentinel health events for use in the surveillance of occupationally related diseases (29). Millar (38) has described surveillance as a tactic comprised of three elements: (*a*) detecting and reporting cases, (*b*) analyzing and synthesizing the incoming reports into an understanding of the situation, and (*c*) acting appropriately.

All of the forms of surveillance can be found today among the activities

Table 1 Precepts for screening programs

In the community[a]	In the workplace for the effects of occupational exposure[b]
The disease should be treatable.	The disease sought should be treatable or useful to the primary prevention of others similarly exposed.
Treatment should be available if asymptomatic disease is detected.	Counseling and other support should be available for those with untreatable disease, as well as treatment if effective.
Conditions sought must have a recognizable latent, asymptomatic stage.	No change
The screening test should be inexpensive and easily administered.	The screening test need not be inexpensive or easily administered.
None	The professionals responsible for screening must be skilled in conducting and interpreting screening tests for occupational disease.
None	Occupational screening tests should be targeted to the specific risks consistent with the exposure or occupation and reassessed periodically to ensure consistency with evolving knowledge.
The timing of the test should be consistent with the natural history of the disease.	Same
The effectiveness of screening in terms of sensitivity, specificity, and predictive value should be considered when choosing screening tests.	Same
None	Neither the normal values for the screening test results nor the predictive value of the test should be assumed to be equivalent to those of the same test used in the community.
None	A priori decisions should be made about the level of abnormal test resusts that will trigger action, and the action appropriate for each level of abnormality.
The screening test should be acceptable to the population.	Same
None	Screening should not be used to limit disease incidence by dismissing workers with abnormal findings from employment.
None	The goals of a screening program, whether the identification of individuals for treatment, an evaluation of primary prevention, or research, should be specified.

[a]Refs. (3, 4, 28).
[b]Ref. (30).

carried out under the aegis of occupational health surveillance. Briefly, we review existant surveillance activities at the national, state, industry, worker, and patient level.

National Surveillance Systems

In 1980, the National Center for Health Statistics published a review of 64 environmental health data systems (39). This compilation includes (*a*) "a review of the data currently available from federal data collection systems on human health and vital events in the American population, pollutants in the ambient or workplace environment of Americans, and personal exposures to suspected hazards suffered by Americans; and (*b*) identification of deficiencies inherent in the use of these and all environmental health data." Data from 64 systems in 18 agencies were identified. Each system was classified according to its purpose. Thirty-five provided data on potential occupational hazards, diseases or both. Only about 16 of these data systems fell within the range of surveillance systems that are designed to provide a continuous flow of nationally representative data linking occupation and disease. The characteristics of these systems were described in 1983 in a study made at the request of the Department of Health and Human Services Committee to Coordinate Environmental and Related Programs (40). Although the purpose of that particular review was occupational cancer, the criticisms of the data systems are relevant to other diseases as well. With regard to their use for estimating the role of occupation in the etiology of cancer, major gaps were identified for these data systems.

1. National Health Interview Survey (41): Cancer is under-reported in household surveys. Data are not collected on all chronic illness from all respondents every year. Occupational information refers only to current occupation.

2. Vital Statistics (42): Efforts to improve the timeliness of data are underway. The number of states coding industry and occupation on the death certificate has increased from 11 in 1979 (43) to about 36 in 1984. There is, however, no compilation of mortality statistics coded for industry and occupation.

3. Annual Occupational Injuries and Illness Survey, Bureau of Labor Statistics: The limitations of this survey for work-related disease with long latencies have been described by Hilaski (44). Diseases of long latency are underreported.

4. Supplementary Data Systems–Bureau of Labor Statistics (45): In 1981, 35 state workers' compensation programs provided the BLS with data on first reports of injury or illness, occupation, and industry. Variation from state to state in workers' compensation laws and probable underreporting of delayed onset work-related illness are the major limitations.

5. Surveillance, Epidemiology, and End Results Program (SEER): Ten geographic areas collect information on cancer site and type, demographic and survival information. Seven of the 10 SEER participants abstract the industry and occupation information as it appears in the medical record. Only two participants, Detroit and Atlanta, code the information for input into the computer file (40).

6. Occupationally Related Disease Case Registers (40): NIOSH maintains two disease registers: angiosarcoma of the liver associated with occupational exposure to vinyl chloride and the beryllium case register. Those are both passive register systems subject to underreporting.

7. Longitudinal Employee–Employer Data (LEED) file of the Social Security Administration (45): Fischbach & Green have used this file to generate hypotheses about relationships between occupation and disability (46). Goldsmith & Herschberg have described the utility of linking the LEED file with mortality data (47). Efforts by staff of the National Cancer Institute and the Social Security Administration are being made to improve the LEED file for studies of occupational disease, particularly cancer (40).

8. Radiation Exposure Information and Reporting System: The US Nuclear Regulatory Commission (NRC) collects and maintains occupational exposure data in this system (48). Lack of standardization of reporting from licensees is a major limitation.

9. Public Health Service Personnel Monitoring Program: The Bureau of Radiological Health monitors about 4500 Public Health Employees in 246 facilities. This group is potentially exposed to low dose levels (49).

Surveillance by States

The situation at the State level is no better. NIOSH staff and the members of the Conference of State and Territorial Epidemiologists (CSTE) are working together to develop a state-based, pilot reporting system for four occupational diseases targeted for prevention by the Surgeon General (66).

These diseases are asbestosis, byssinosis, silicosis, and coal workers' pneumonoconiosis. They share these characteristics: (*a*) their etiologies are well understood; (*b*) they result in almost every case from exposures that occur at work; (*c*) they are easily diagnosed; and (*d*) they are preventable. The NIOSH/CSTE objective is to implement this pilot program and then to expand it to a state-based national system for a broad range of occupationally related diseases.

Efforts are being made to strengthen occupational injury and illness surveillance by state health departments. Funds are provided by NIOSH to states through a means of cooperative agreements. Although these systems are mainly based on mortality records, several states are now exploring the use of occupational disease surveillance systems that are based on other data sources, e.g. hospital discharge records or workers' compensation files.

Surveillance by Industry

Employers are showing increased interest in developing surveillance systems from the records they maintain on agents, workplace conditions, and indices of employees' health. In December 1983 the American Conference of Governmental Industrial Hygienists held a symposium on the topic of Computerized Occupational Health Record Systems (19). An inventory of firms offering occupational health and hazard data-base packages appeared recently in the *Chemical Week* (67). This interest is a reaction partly to new record-keeping requirements (69) and partly to the ubiquitous nature of computer systems that can aggregate and manipulate large amounts of data. Additional emphasis on the selection of data to be collected and on their analysis is needed to take full advantage of these industry-based systems.

Surveillance by the Practioner

The astute physician has been responsible for the detection of many epidemics of occupational disease [e.g. angiosarcoma and vinyl chloride (64), bis-chloromethylether and lung cancer (65), DBCP and oligospermia (11)]. However, physicians fail frequently to consider disease entities of occupational or environmental origin in forming their differential diagnoses (60). Widespread neglect of the occupational history has been suggested to form the basis for this oversight (61). That neglect may, in turn, be a consequence of failure to emphasize the occupational history in the literature on physical diagnosis and internal medicine (62) and may be a result of inadequate training in occupational medicine in most medical schools (63).

The sentinel health event (29) concept offers an approach to improved clinical recognition of occupationally provoked disease. A sentinel health event (occupational) is defined as "an unnecessary disease, disability, or untimely death which is occupationally related and whose occurrence may: (1) provide the impetus for epidemiologic or industrial hygiene studies; or (2) serve as a warning signal that materials substitution, engineering controls, personal protection or medical care may be required." A concise table (29) has been developed that lists those sentinel diseases for which there exists a high likelihood of occupational origin.

These occupational health surveillance efforts will provide new opportunities to identify work-related diseases and to initiate a chain of events that will prevent their further occurrence.

CONCLUSION

The antithesis of early detection is the identification of advanced or symptomatic disease. Those interested in the safety and health of workers will be enticed by the prospects of biological monitoring, screening, and surveillance contributing to prevention. Whether any one of these techniques is of value in a particular setting should be considered critically and not left to the overly enthusiastic or hypercritical, the "evangelists and snails" (4). Decisions of whether to adopt these procedures are important because not only are such procedures of potential value, but they also represent investment of resources that might otherwise be applied to more effective measures of primary prevention; at worst these techniques can be detrimental.

The data generated by biological monitoring, medical screening, environmental monitoring, sickness benefit, or other systems can be collected, assessed, and used productively in a surveillance program. For surveillance to work effectively at the plant, state, or even the national level it must involve more than just the collection and tabulation of data from groups. Public health surveillance must effectively use this health data to design or alter health policies and intervention programs.

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