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PROBLEMS OF SURVEILLANCE IN OCCUPATIONAL RESPIRATORY HAZARDS

B. GANDEVIA
Division of Thoracic Medicine, Prince Henry Hospital, Sydney, Australia

ABSTRACT

At their worst, surveillance programmes offer no more than a means of occupying the time of the medical staff, placating the work force and consoling the managerial conscience. At their best, conceived as prospective epidemiological studies, they may enhance understanding of the medical and industrial factors producing respiratory disorders and thus direct control along scientific lines. Effective surveillance design requires an appreciation of the nature of the respiratory disease and of the hazard, as well as an understanding of epidemiological principles and techniques. Surveillance must be planned to protect both the individual and the group, but the increased sensitivity of group surveillance, while not contrary to the welfare of the individual, offers better protection both to management and the work force.

This paper examines the design and purpose of surveillance programmes for modern occupational respiratory hazards. Surveillance implies more than merely "surveying" a population, as in the ritualistic annual medical examination; it should be designed as a prospective epidemiological survey orientated towards the early detection of defined respiratory syndromes. This concept stresses the role of studying the group as well as the individual, an approach which increases sensitivity through the use of statistical methods appropriate to groups. The longitudinal study of groups* classified by exposure and task, perhaps including a comparable group of unexposed subjects, offers greater prospect of profit in a cost-benefit analysis than unplanned routine examinations.

The influence of the nature of the syndrome and of the hazard are reviewed in relation to the design of appropriate surveillance programmes. Specified criteria for the identification of "cases" must be defined in advance, and their future planned.

THE NATURE OF THE SYNDROME

For conditions such as mesothelioma and bronchial carcinoma surveillance has nothing to offer the individual as "early" diagnosis has a negligible effect on outcome. When sufficiently large groups can be defined and followed up, the

* The term "group" is used to describe a section of the work force specifically at risk; it may be only part of an occupational population.

determination of incidence has practical significance, fully realizable only if data have been collected prospectively on smoking habits and carcinogen exposure.

The insidious onset of specific syndromes, best exemplified by silicosis, coal pneumoconiosis and asbestosis, poses a different series of problems. For the first two of these disorders early radiographic changes of reasonable specificity can be detected in the individual. Modern reading techniques also allow this method to be used in surveillance of the group. In asbestosis, radiological change is not necessarily early; it is less readily identified and less specific. Emphasis has therefore to be given to clinical signs and functional tests. A variety of lung function tests has been applied in a predictably futile endeavour to find a "best" test; the pathology and pathogenesis of a disease attributable to dust of varying physical and chemical properties in a host of different industrial situations makes it unlikely that a "best" test will emerge. It is even unpredictable on present knowledge whether functional or radiographic changes will come "first" (also implying an illogical hypothesis). The test currently considered "best" in statistical terms is the vital capacity, which has the major disadvantage of being non-specific. On present information, all three approaches (clinical, functional and radiographic) should be included in any surveillance programme. The functional tests should include indices of transfer factor and respiratory mechanics in addition to the simple ventilatory measurements.

Surveillance for the "classical" dust hazards is of decreasing significance as engineering control reduces or eliminates the hazard in most countries and processes. Of greater importance amidst the complexities of the modern industrial environment are the "asthma-bronchitis" syndromes,* and the question of excess morbidity from non-specific chronic respiratory disease. The former are usually associated with an acute clinical syndrome, although "chronic asthma" develops more or less insidiously in response to some inhalants (e.g., hard-metal fume, *Thuja plicata*). Symptoms are not always reported, perhaps for socio-economic reasons, perhaps because they are accepted as more or less inevitable by the work force (e.g., metal fume fever, the chest tightness of cotton dust exposure). An inhalant producing disorder in small peripheral airways, or "bronchiolitis", may be asymptomatic, or cause only a mild cough (as occurred with proteolytic enzymes). Pre-existing respiratory disease and smoking may influence the incidence, prevalence and natural history of these specific disorders. Surveillance programmes need to take these features into account, and may also have to include measures to identify idiosyncrasy or hypersensitivity. In the individual, work habits and techniques may be contributory, while shift differences in procedures and supervision also need consideration.

Essential to the design of surveillance programmes related to acute or chronic "asthma-bronchitis" syndromes, and also to interstitial disorders, is the pre-placement or pre-employment examination. This must identify pre-existing

*This term combines labels commonly given by doctors to acute, often recurrent, respiratory syndromes with little diagnostic discretion, especially as some of these occupational syndromes have features which are not characteristic of the non-occupational disease. Because the clinical and functional features may vary both within and between each inhalant, I prefer to avoid the term of occupational "asthma" (or "bronchitis"), and also to avoid the implications and limitations of diagnostic labels, by referring to the respiratory syndrome associated with a particular inhalant.

disease or characteristics suggestive of undue susceptibility, but more importantly, it must employ assessments and record information using exactly the same tests and techniques as in the surveillance programme. It thus becomes the baseline of a prospective epidemiological survey. If any selection is applied at this stage, the criteria must be clearly defined and the same information recorded for other groups in the work force. Later inappropriate comparisons between different work groups may then be avoided, or the remainder of the work force sampled appropriately if a control group is required. An early aim of surveillance in an occupation with a risk of acute respiratory disorder should in fact be to test criteria for selection, or exclusion, for their predictive value.

Surveillance programmes to detect acute or chronic "asthma", "bronchiolitis", or "alveolitis", or an excess of "airways obstruction", "chronic bronchitis" or "emphysema", will require radically different designs, questions, tests and analytical procedures. "Routine" medical examinations cannot contribute to these problems unless they employ techniques which are epidemiologically sound and related to the particular "clinical" problem. In relating the design of surveillance programmes to the nature of the syndrome (sometimes only suspected) there are two possible sources of error. First, extrapolation from clinical experience to the epidemiological situation may be fallacious. For example, clinical asbestosis a decade or so ago was associated with a gross reduction in transfer factor. It does not follow that this will be the most sensitive, or overall the most useful, test in the surveillance of a "healthy" occupational population. There is at least a theoretical possibility that dysfunction in small airways or an increase in pulmonary elastic recoil might prove more significant.

The second risk is the assumption that a given inhalant produces one characteristic disorder. Bird-fanciers and farmers suffer from asthma as well as so-called "allergic alveolitis", a syndrome which is invariably associated with bronchiolar disease, and often also with a component of large airway dysfunction ("asthma"). Probably all causes of allergic alveolitis also produce asthma; contrariwise, western red cedar, a common cause of asthma, has been associated with interstitial and bronchiolar inflammation proven at biopsy in at least two cases known to me. Surveillance programmes must be based on what is known or reasonably supposed, but concepts should not be unduly constricted by preconceived ideas.

THE NATURE OF THE HAZARD

"Hazard" in this context includes the physico-chemical properties of the inhalants as well as the industrial circumstances in which they are encountered.

The potential pathogenicity of most inhalants is well-known, and, in general, it is known whether their effects in given concentrations are likely to be acute, subacute or chronic, transient or cumulative. Similarly, they may be classified as mainly irritant, sensitising, fibrogenic, pharmacologically active (organic phosphates, cotton) or carcinogenic. Less relevant in the present context are inhalants which merely accumulate in the lung without significant functional effect (tin, barium), or which produce systemic effects. Clearly these

considerations influence surveillance; within the irritant class, for example, the solubility of a gas directs attention either to the upper or lower respiratory tract.

Less attention is usually paid to the nature of the exposure in relation to surveillance. In the classical pneumoconioses, exposure occurred daily more or less consistently over years. From the surveillance viewpoint, this implies a relatively predictable and regular exposure. The timing of surveillance presupposes a low attack rate over years, rather than a high incidence in any one year. Constant exposures also occur to other occupational inhalants, but in some, such as chlorine and other irritants, peak, or accident, concentrations are of overriding importance, especially when recurring "minor accidents" may occur. Exposure to other inhalants, particularly those related to "asthma-bronchitis" syndromes, may be episodic (frequent or occasional), as in processing a variety of woods handling transport cargoes, or working with a variety of chemicals. In asthmatic or hypersensitivity syndromes, exposures may be below the threshold limit values, although reactions are dose-related even within this range. Reaction is also influenced by recent past experience (e.g. after a period off work, asthmatic symptoms may take up to a fortnight of further exposure to recur). Asthma is common in some industries where the TLV is that of a "nuisance dust" rather than a pathogen (e.g. grain and wood dusts). The problems are complicated when the causal constituent of a complex inhalant is not known, where it is produced only irregularly or accidentally, or where there is some effect apparently disproportionate to environmental levels (e.g. as a result of adsorption or synergism). The acute respiratory syndrome of aluminium smelting appears to be out of proportion to the environmental levels of fluoride, sulphur dioxide or vanadium, but nonetheless it can be related to those processes exposing workers to greater amounts of total fume. Finally, in a few instances, particularly in countries where aggravation of pre-existing disease forms grounds for compensation, isolated exposures to relatively high, but not necessarily frankly toxic, concentrations may assume at least medico-legal significance. Surveillance programmes cannot afford to oversimplify the difficulties implicit in these considerations.

It follows that surveillance cannot be dismissed simply because environmental estimates of the hazard are usually within the accepted range (in itself a statistical concept with an accepted risk of underestimate). Furthermore, the surveillance programme must be flexible if it is to take account of peak or accidental exposures, or high transient exposures due to process problems, plant breakdowns or ventilation failures.

The possibility of more than one pathway of pathogenesis also needs consideration. Toluene di-isocyanate is irritant to all in high enough concentrations, when it may produce "pneumonitis", but it is chiefly recognised as a sensitising agent producing "asthma". Proteolytic enzymes cause hypersensitivity states but peak (accidental) concentrations are responsible for acute bronchiolitis (often subclinical), perhaps eventually responsible for loss of pulmonary elastic recoil. A surveillance programme aimed at the hypersensitivity phenomena and related to "standard" environmental enzyme levels may

overlook what might ultimately prove to be the more permanent and more serious disorder. This sequence is a reminder that because occupational asthma commonly disappears after removal from the causal inhalant, attention may be diverted from the possibility that long-term subclinical effects may lead to disability.

Occasionally one encounters a respiratory syndrome without a known specific causal agent. The influence this lack of a specific agent may have is illustrated by an industry in which over 25% of the relevant occupational group developed asthma. Largely on the grounds of clinical experience, an allergist attributed the problem to the inhalation of the raw organic material from which ultimately morphine was prepared. Subsequently it emerged that the first attack had invariably occurred during contact with the final product in a finely divided form. The implications of alternative hypotheses to surveillance are evident; emphasis in this example is directed to opposite ends of the plant. It is, of course, apparent that both control and surveillance measures are best based on accurate identification of a specific agent, or at worst, a specific process.

THE DESIGN OF SURVEILLANCE PROGRAMMES

From the foregoing it emerges that a repetitive routine medical examination cannot provide adequate surveillance whether in terms of an effective safeguard to exposed individuals and groups, or to management in its overall concern with the operating conditions affecting the health of its employees. Similarly, it is not possible to design a single programme for all hazards and all occupational and socio-economic environments. It is possible to examine some guiding principles, based on the assumptions that every effort has been made to comprehend the nature of the respiratory syndrome and the nature of the hazard.

First, the design should be on the basis of a prospective epidemiological survey, partly because essential aims of surveillance are likely to include (at least initially) the study of the natural history of the disorder, including its incidence, of the identification of predisposing or aggravating factors, either in personnel or in the work environment and of the long-term effects of exposure, especially on the prevalence or severity of chronic non-specific respiratory disorders.

Secondly, as far as possible, specific aims and objectives must be laid down in advance. These may be serial, in that an initial aim may be simply to see whether an alleged respiratory syndrome is present; later aims may be to determine its defining characteristics and its incidence in different areas of the plant. Early objectives may be the definition of susceptible subjects, while later ones may include the assessment of irreversible respiratory damage or the effects of control measures.

Thirdly, particular attention must be paid to those who leave the job, largely because the reasons for leaving may be highly relevant but also to resolve as far as possible the difficulty of all prospective surveys, that of dealing with a survivor population. It can be argued that the incidence of acute industrial syndromes, or an industrially determined excess prevalence of chronic non

-specific respiratory disease may be better reflected in those leaving the industry than in those who remain in it. Within practical limitations, surveillance should include review of all subjects leaving the industry. Put another way, acute respiratory symptoms, not necessarily severe or disabling, are an often overlooked cause of a high labour turnover in the early months of employment. Socio-economic factors may also condition the nature of a survivor population.

An epidemiological basis to surveillance programmes implies attention to methodology. In particular, it tends to exclude the collection of useless information by directing design towards confirming or denying a hypothesis, or series of hypotheses; surveillance is not just a data-collection exercise. Questionnaires should be worded with special care. To minimise interviewer influence (particularly where interviewers may change) these should probably be self-administered. Clinical signs and tests should be selected as appropriate to the problem; those which are insensitive, unreproducible or low in discrimination should be discarded. For example, if FEV_1 and FVC are being measured, auscultation of the chest for wheezing or high-pitched rhonchi is superfluous. Similarly, percussion is not contributory if a chest radiograph is being taken. Chest examination reduces itself to basal auscultation for fine rales or crepitations (where the problem requires it) and a request for a cough (to determine whether it is "loose" or "dry").

Selection of tests must be based on what is appropriate not only for the individual but also for the group, and indeed the latter deserves prime consideration. Thus, an estimation of vital capacity has an error of, say, $+5\%$; as this error is about five fimes the expected annual decline, the test has little value to the individual until sufficient estimations have been made to enable his own rate of decline to be calculated with some accuracy. By contrast, the mean value for a group when compared with an appropriate control group (rather than with "normal standards") may reveal significant differences in rate of decline at an "early" stage, both in terms of time and pathology.

The timing of surveillance examinations is influenced by the nature of the syndrome and the nature of the hazard. No attention should be paid to the last surviving influence of astrology on medicine, namely, the cultural faith in an annual medical examination. If the methods and groups used are sufficiently sensitive, intervals of three or more years may be adequate. We have adopted this interval in surveillance of an asbestos-exposed work force where an extended range of lung function tests, including lung mechanics, can be used in addition to other conventional methods of examination. The disorder (asbestosis) is insidious in onset, and the hazard may be expected to decrease rather than increase.

The initial survey of a surveillance programme should aim to identify all cases of the disorder in question, and preferably all "suspects"; these may require their own surveillance programme. Initial identification of these cases, and their separate supervision, may permit some modification and simplification of the main surveillance programme, whereas their inclusion may introduce an unpredictable bias. Their exclusion may produce a source of bias in following the remainder, but this is at least known.

Acute or subacute syndromes demand more frequent surveillance, and indeed one aim of the programme may be to determine this frequency. These syndromes often call for a design which incorporates individual monitoring "on the job", particularly perhaps ventilatory measurements before and during a shift. In an aluminium smelting company, monitoring of small subgroups on a rotating basis has been planned to allow systematic comparisons between potlines with differing procedures and ventilation systems. Planned systematic sampling has considerable advantages over random sampling in that it enables specific comparisons between groups or between situations; purely random sampling is mainly of value to the individual. There are no ethical problems in using the usual occupational exposure as a challenge or provocation test, and indeed, there is rather the reverse obligation to monitor its effects.

When large populations produce logistic difficulties, the concept of surveillance as a prospective epidemiological study encourages the use of carefully designed sampling methods. In the past, we have been reluctant to recommend the use of samples, chiefly because of complaints of inclusion or exclusion on the part of individuals or groups. More recently, we have found greater readiness on the part of unions and management to accept the principle of sampling where the advantages of more detailed study of small subgroups can be demonstrated, and where it can be seen that the results of these studies will in due course be related to the working conditions of the entire work force. Sampling should usually be associated with some less comprehensive surveillance for the whole group, and the primary sample should comprise as many as possible of those "most heavily exposed". "Control" groups need to be carefully chosen as comparable; factors to be considered in addition to exposure are age, smoking habits, duration of employment, and any selection factors, medical, educational or socio-economic, which may be affecting selection into the "control" or "test" groups.

THE IDENTIFICATION OF CASES, AND THEIR FATE

Criteria for the identification of cases or of suspect cases must be laid down as part of the design of the surveillance programme; it may be appropriate to devise a graded system. Acceptance of the surveillance programme will almost always require advance knowledge as to what is to be done with individuals with real or suspected disorder, or what steps are to be taken if trends in the group are adverse (before individual cases can be identified with certainty). Since every situation will be different, no guidelines are possible but the fallacy of reference to "normal standards" for lung function tests deserves mention. Predicted normal values for FEV_1 and VC in different series in the literature differ by as much as about 500 ml, and we have found similar differences between "healthy" subjects in different occupational groups. Many factors influence selection into an occupation, and, directly or indirectly, ventilatory capacity is amongst these. The more esoteric the tests, the smaller and less representative are the series on which "normal standards" tend to be based. In an occupational context, separate standards of "normality" would presumably be necessary for smokers. Finally,

acceptance of an arbitrary level of, say, less than 75% of predicted normal for VC as "abnormal", implies that those with normally low VCs will soon fall into the diseased group, while those beginning with high VCs, of say 120% of predicted normal, will not be "diagnosed" until their VC has fallen by nearly half its original value. It is preferable that the surveillance programme should be used to establish normal standards, especially for decline of lung function, within its own industry rather than that findings should be related to textbook norms.

"Early" diagnosis, and the diagnosis of minimal disease (not necessarily the same thing), in well-designed surveillance programmes do not necessarily carry the prognostic implications of established clinical disease. Action required may be no more than an individual modification of work environment as an initial step, but probably workers in this category warrant a more specific and intensive surveillance programme of their own. "Early" asbestosis, as diagnosed with all modern aids, is most unlikely to have the poor prognosis of clinical asbestosis as diagnosed one or two decades ago. It may or may not be unreasonable to exclude an employee from remunerative skilled work with "early" disease, or if his occupational asthma can be controlled by use of a simple respirator. Surveillance is required to answer these questions.

ENVIRONMENTAL MEASUREMENTS

Positional environmental samples have a well-recognised role in monitoring the control of industrial processes. In surveillance or biological monitoring programmes personal sampling is preferable and may permit understanding of dose-response relationships. However, even personal samples have limited value when exposures are within the TLV (in which range the method of measurement may also be insensitive), when peak or accidental exposures are those most relevant, or when the disorder is related to individual susceptibility or hypersensitivity. Environmental and biological monitoring must be seen as complementary, not as mutually exclusive, procedures.