AUTOMATED MULTIPHASIC HEALTH TESTING

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ADVANCES in automation and instrumentation have brought medicine and allied disciplines to the brink of a new era in health care. It is now feasible to screen total populations or selected subgroups for asymptomatic disease at reasonable cost and with minimal use of physician time.

Medical personnel and facilities will be progressively incapable of delivering health services if the population born after World War II in the United States is allowed to enter middle age with undetected and unaltered disease. Because of this population boom the portion of the population aged 25 to 45, for example, will increase by 69 percent by 1990 (*1*).

Chronic illness costs our economy an estimated $57.8 million annually. Included in this amount are direct costs of treatment and care and the loss of present and potential income (*2*).

Total health care implies a continuum from prevention to early detection of a disease through the stages of clinical disease, rehabilitation, and demise. Clearly, prevention and early detection are the first—and only the first—steps toward solving this situation.

We define the word "screening" very explicitly. It is the presumptive identification of previously unrecognized disease or defect, by the application of tests, examinations, or other procedures which can be applied rapidly. This is the definition of the Commission on Chronic Illness Conference (*3*).

The salient points of this definition are presumptive, unrecognized, and rapid. For most investigators, screening implies only the differentiation of normal from abnormal, hence the emphasis on the word presumptive; we have progressed little if we redetect previously known disease, hence unrecognized is stressed. To be sure, there is a place for surveillance of subjects with known disease for a status check or a followup, but none of these is screening. The special feature of modern screening clinics is rapidity, which reduces both the costs and the loss of time for patients and personnel alike.

Traditionally, disease detection proceeds through a progressive system of procedures and tests that enable the physician to arrive at a definitive diagnosis. A classic example of such a uniphasic series of tests can be drawn from pulmonary tuberculosis detection; "presumptively" afflicted persons are identified by mass chest X-ray units. Positive skin tests for tuberculosis delineate some of these persons as "probably" tuberculous, and obtaining a positive culture for tuberculosis "definitely" diagnoses the disease. Note that mass X-ray is the screening procedure in this example.

Those involved in health testing have long known that health-service consumers, like other consumers, prefer one-stop service. So several tests are performed at a single visit, but each series of tests from presumptive to definitive is unidirectional, that is, it leads to one diagnosis independently. An example of another series of tests that could be performed in conjunction with tuberculosis detection is glaucoma testing. The presumptive tests for this prevalent disease, subject to some local option, are tonometry (the indirect measurement of pressure within the eye) or visualization of the retina by photography, or both. Additional information for the

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establishment of the diagnosis is obtained by applying progressively sophisticated techniques leading to the definitive test of tonography.

Most multiphasic clinics are at the unidirectional level of sophistication. Some procedures and techniques are automated, but they proceed in an essentially unidirectional manner. It is incorrect to speak of such units as multiphasic screening clinics if a mechanism exists within the clinic for validation, followup, or treatment of presumptive findings. The true multiphasic screening clinic includes only a series of presumptive tests. Confirmatory tests, followup procedures, and therapy are not properly within the scope of screening clinics.

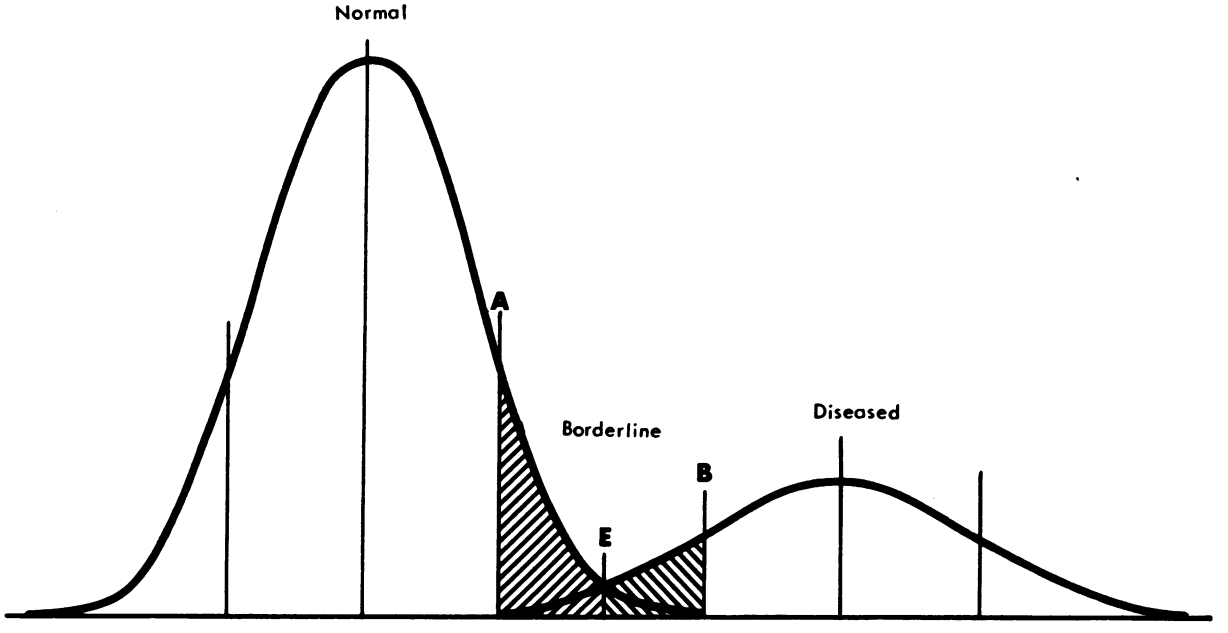
It is well known that existing specialty clinics evaluate only their particular area of interests, thereby overlooking other diagnoses. Communication between different subspecialty clinics is notoriously poor. Duplication of the clerical tasks in outpatient clinics is great, and the inconvenience to patients in time, travel, and job absenteeism is marked. The potential of a properly automated screening clinic is to minimize these costly nuisances and improve patient care.

An example of a multiphasic screening clinic is one operated by the city of Milwaukee under the direction of Dr. Edward R. Krumbiegel, commissioner of health, and financed in part by the Public Health Service (*4*). Residents of Milwaukee aged 40 and over may undergo a series of tests designed to detect loss of sight and hearing, diabetes, glaucoma, breast cancer, cancer of the cervix, and high blood pressure. Included are lung function tests, electrocardiogram, chest X-ray, blood tests, and a self-administered medical history. The findings are sent to the subject's private physican, who schedules confirmatory tests, followup, and treatment if necessary.

We contend that proper use of automation will allow for predictive multiphasic testing. If results of screening tests were available rapidly (that is, on-line), the definitive tests could be scheduled before the subject leaves the unit. The necessity of rescheduling patients for confirmatory tests would be reduced. The physician's time would be more productive, since data would be available to him as needed. For example, if the results of two screening tests, the EKG and spirogram, were rapidly available and indicated a probable chest abnormality, a definitive test could be performed before the subject left the clinic. Intermediate tests would not be needed.

The traditional examination by body systems (that is, head, eyes, ears, lungs, heart, and so

Distribution of a variable in a population



Bimodal distribution

forth) may well be replaced by an examination sequence tailored to characteristics of patient flow. All the tests that can be performed in one body position may be grouped together, or all the tests that are measured by the same basic kind of instrument might be combined at one station.

The Kaiser-Permanente Multitest Unit (*5*) employs some of these principles in acquisition, measurement, and recordkeeping. According to Collen, automation provides "improved quality control, reduced costs, and substitutes hours for days in patient and physician time" (*6*).

We offer the following guidelines to those planning a multitest unit.

1. *Know your population.* The male-to-female ratio, age, occupation, and socioeconomic level of the population will determine the characteristics of patient flow, choice of tests to be performed, and the level of detection.

The level of detection refers to the ratio of sensitivity to specificity (see chart). If the result of a test or procedure has a bimodal distribution within a population, that is, a group of normals and abnormals who overlap (line E on the chart), the point of borderline determination can be arbitrarily altered (toward line A on the chart) so that all the diseased are identified, but a relatively large number of normal persons will also be included. The consequence of this tactic is to load the validation or followup facilities with many normal subjects who require delabeling. However, the necessity of identifying all who may possibly be diseased may be so compelling (because of the nature of the disease) as to make worthwhile the retesting of a proportionately large number of false positives.

2. *Clearly define your goals.* Another way of saying this is, "How are the data going to be used?" For health education of the public? For screening only or for screening and definitive diagnosis, or both? Is only curable disease or only prevalent disease to be detected? Are clinical applications, such as preadmission screening of patients for elective surgery, the primary interest? Or are the reasons for screening some combination of these?

3. *Know the limits of instrumentation.* Physical examination has not been replaced by a series of machine-performed tests. Automation and instrumentation merely aid the examiner. Great variability exists in the measurement of signals, whether by hand or by machine. Availability of instrumentation relates directly to cost. Duplicate equipment may be necessary to insure full-time operation of the testing unit, and this factor increases cost. An electronically oriented technician who can troubleshoot equipment is integral to a highly instrumented unit.

Instrumentation and automation have not supplanted the physician and the physical examination. Large portions of the examination, such as the search for gastrointestinal and neurological conditions, remain unautomated. Once the total purpose for data collection is established, automated techniques can be rationally applied to serve that purpose.

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