Intelligent Database Generated Occupational Questionnaire System

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Abstract **Author Information** **Article Outline**

Obtaining an adequate occupational history requires special expertise to “ask the right questions” that are relevant to a particular patient’s specific health conditions and potential exposures. This article describes a way to systematically accomplish this by means of a computer system that can overcome limited availability of necessary clinical occupational health expertise. The Intelligent Questionnaire system is a computer-based system for generating case-specific questionnaires about the influence of work on respiratory disease. Intelligent Questionnaire includes three databases: Questions, Responses, and Calls (clues to identify questions). The Questionnaire also arranges questions in a logical manner and provides a customized data entry screen for each subject. This approach provides primary practitioners with expertise on a case-by-case basis. It also facilitates occupational health surveillance because it allows acquiring detailed case-specific information in a systematic fashion. A computer-based system can facilitate obtaining occupational histories with high specificity and consistency without depending on general availability of a human occupational health clinical expertise.

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Asking the right question is the first step toward getting the right answer. Specific knowledge is needed to pose the specific questions for gaining information to identify work-disease relationships. Exhortations to clinicians to “take a complete occupational history” may not be helpful if the clinicians lack the necessary knowledge and time to generate the proper specific questions or to consult reference material. Exposure and health outcome classification for surveillance also requires collection of situation specific information about work processes, the patient’s specific tasks, temporal relationships, and clinical details.

Two different approaches have been used to obtain case-specific clinical and workplace information: (1) the extensive and highly specific interview, or (2) completion of a limited fixed-format questionnaire. This article describes a means to systematically facilitate obtaining an adequate history by using a computer-based “intelligent database” system to overcome limited availability of necessary clinical occupational health expertise.

Methods

The Occupational Respiratory Disease Evaluation and Rehabilitation System (ORDERS) project seeks to provide the benefit of specialists’ approaches (occupational medicine, pulmonary medicine, industrial hygiene) to primary care physicians who actually evaluate and treat most workers. The project seeks to foster recognition and prevention of occupational respiratory disease and to facilitate workplace accommodation of individuals with nonoccupational disease that impedes work ability. Primary care providers in four southern California counties may request assistance with patient care. An interviewer verbally administers a computer-assisted questionnaire; a team of experts reviews this information and makes suggestions for the primary care provider. To the extent possible, such suggestions should be highly specific. By intent, the interviewers are not experienced physicians or industrial hygienists.

To facilitate the interview process, an intelligent database system was developed to store a large number of questions that may be relevant to specific clinical or work situations. A series of programs was developed to choose appropriate questions for each case and to structure the questionnaire in a useful manner. The combined database and front-end interface programs are referred to as the Intelligent Questionnaire (IQ) system.

Figure 1 summarizes the overall operations of IQ in the ORDERS project. To develop this system, a “bottom –up” approach was used. Each new subject referred to the ORDERS project is interviewed very briefly to obtain consent for participation and to collect limited information (current job title, current respiratory diagnoses, and any self-statement by the patient about concerns regarding respiratory exposures). The information is comparable with that collected in the very short, standard format questionnaires commonly used. This requires less than 5 minutes.

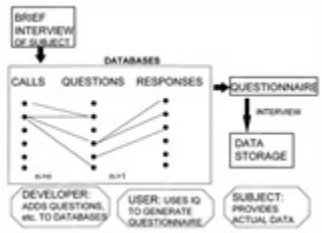

Fig. 1

On the basis of this limited information, a detailed questionnaire for the specific subject is produced to include the most relevant and specific questions. This system was implemented in a PC-compatible, commercially available database management system. The questions come from two sources: questions already in the database itself or questions from an expert panel. The interviewer uses IQ to select relevant questions already in the database. In addition, the brief information (job title, industry, medical diagnosis) is presented to an expert panel (an occupational/pulmonary physician, an occupational physician, and an industrial hygienist). Panel members are asked to suggest the most directly relevant questions that they would want answered to collect diagnostic information and make control recommendations for the primary physician. Each new question is then linked to one or more indexing codes (“calls”). In addition to being applied to the instant case, these questions are stored in the database system for subsequent use. As the IQ “Question Bank” enlarges with progressive experience, the number of questions that the expert panel must add decreases because it is more likely that the needed information has already been incorporated.

In addition to the Question database, there is a Response database. Each question is linked to a set of possible responses. When questions are selected for inclusion, the relevant choices are automatically linked. Wherever possible, a standardized format is used for consistency and ease of use. Standard formats include dichotomous (yes or no), qualitative relative frequency (never, rarely, occasionally, always), quantitative frequency (daily, once per week, etc), date, and Likert Scale (strongly agree, neutral, strongly disagree). When necessary, less generalizable response sets are needed. For example, it is inefficient to ask a carpenter a series of yes/no questions (such as “Do you use pine? Do you use mahogany?) rather than ”Which of the following woods do you use?“ linked to a single response set listing the types of woods.

Each question is linked to one or more “calls” (keywords, such as the name of a job or a disease). Technically, the relations are “many to many,” such that a single keyword can point to many questions, and a single question may be called by many different keywords (eg, “painter” points to questions about use of respirators, exposure to solvents, work with isocyanates, symptoms of asthma, etc. Many other calls also point to respirator use).

In addition to maintaining a compendium of questions, the IQ system guides the interviewer to choose the appropriate questions for any situation. The IQ system organizes the questions so that they are presented in the final questionnaire in a meaningful order. The system also allows the interviewer to edit and print questionnaires. It also creates a custom input screen for each subject (as the questionnaire is created, it automatically presents appropriate response choices).

Notices about availability of free services as part of the ORDERS project were sent to physicians in the Los Angeles area. In addition, staff members visited hospitals and ambulatory care centers. In several locations (two county hospitals and several health maintenance organization [HMO] centers), a staff member visited on a regular (eg, biweekly) basis.

The specificity of individual items available for inclusion was rated. An item of high specificity is applicable only to a single industry or disease (for example, “When working as a carpenter, how frequently do you use pine wood?”). A moderate specificity item has applicability in multiple settings (for example, “How regularly do you employ a respirator”?) A low specificity item is useful for virtually every subject (for example, “Are you currently working” or “What is your job title?”). A 5-point scale for specificity was used, for which 1 = highly specific and 5 = very general.

The results of utilization by the first 389 subjects are described here. Forty nine percent were male. The average age was 48.1 years (range, 18 to 96). Eight percent spoke only Spanish.

Results

A baseline question set with generic questions was supplemented with case-specific questions on an as-needed basis. There were 759 questions in the Question Bank. There was a total of 80 calls (terms that should trigger a particular question). Each question was relevant to an average of 1.67 jobs or diseases; some were relevant to as many as 30 items.

Table 1 includes examples of questions and response set types. Questions a, b, c, and d exemplify the types of questions that should be asked of workers in selected occupations. However, they are too specific to be routinely included in all questionnaires. In addition, they require expert knowledge that is not generally available. Question e is less specific and requires less expert knowledge; however, it would be inappropriate to be included routinely. Question f is very generic and illustrates the type of question commonly asked in general questionnaires. Table 2 describes the question types. Questions included those related to workplace factors (eg, Job, Agents, Tasks, or Work Relatedness of Symptoms), clinical factors (eg, disease, symptoms), or general (Personal Habits, General Characteristics). More questions dealt with exposures than with diseases. Table 2 also describes the specificity of the questions. On a 5-point scale, the mean specificity rating was 2.28. Specificity was greater for workplace factors than for symptoms/diseases.

Table 1

Table 2

There are 124 response sets. Questions are linked to response sets in a “many to one” manner (each question is linked to a single response set, but a response set may be used by many questions). Thus, the number of questions linked to a response set correlates with its generality. The mean number of questions linked per response set was 6.06 (range 1 to 219). One hundred and four were linked to two or fewer questions; such questions typically referred to specific agents or tasks associated with certain jobs.

Empiric Results

Results based on the first 389 subjects are summarized in Table 2. Each questionnaire contained an average of 42.8 items with a standard deviation of 30.86 and a range of 8 to 392. Of these, several were generically used in all questionnaires (such as name, age). Relatively few questions were of the type that are typically

employed in generic questionnaires. The majority, however, were specific for the patient's job and disease. As shown in Table 2, the most frequent question topics other than general indentifiers were disease and task. Combining the workplace-related groupings (agent, job, task, work-related symptoms), workplace factors were more commonly addressed than typical clinical factors.

The questionnaires addressed several topics ("object units") per subject. These included jobs and diseases. For example, a subject who has asthma and has had three jobs (baker, butcher, candle-maker) would be considered to have four object units. The number of topics varied from three (introductory questions, one disease, one job) to nine.

The specificity of the questions actually used is shown in Table 2. The overall mean specificity was 2.47 (standard deviation = 1.70). Notably, the questions that were related to agents and jobs were much more specific than those that addressed work-relatedness of symptoms in a general fashion. The latter are comparable with widely used items such as, "Do your symptoms become worse at work?"

Discussion

Clinical occupational medicine (in both primary care and speciality settings) needs extensive information (such as exposures and control measures) that is not normally available to most clinicians. Public health depends on collection and analysis of aggregate information from individual clinical encounters. A great deal is known about occupational hazards, mechanisms by which such exposures lead to disease/injury, and specific preventive measures. Nevertheless, this information often is not distributed so that individual patients receive the benefit of such knowledge, and public health surveillance often does not acquire the necessary information from clinical encounters. IQ is both a computer system and a health care service delivery strategy to help supply the knowledge and motivation necessary meet these needs.

IQ is structured as a *computer-based intelligent database* to facilitate knowledge representation and utilization and to develop questionnaires for specific settings. As shown in Fig. 1 and Table 2, IQ relies on the application of each individual element to many different situations. For example, questions are applicable to an average of 1.67 "calls," and each call is linked to an average of 8.17 questions. This differs from the "modular" computer questionnaire system of Stewart et al [1,2] in which a fixed, unique set of questions is assigned to each of a limited group of calls. In the empiric application trial, some questions were used in nearly all subjects (such as age, gender, job title); questions of this type would be available in most routine occupational health questionnaires. However, most questions were applicable to only selected subjects; the average question was used 7.43 times. An average of 42.85 questions were presented to each person, allowing insight into the person's occupational history.

Questions were reasonably specific. Table 2 shows that the average specificity rating for questions was 2.28 on a 5-point scale (1 = very specific). In the empiric trial, the average specificity of questions used was 2.47. Thus, the use of a large question bank with a computer-assisted selection process permits more in-depth and focused questioning than is available from routine questionnaires.

As a *health care service delivery method*, the system bypasses dependence on both the time and knowledge of busy clinicians. Generating the questions asked of each patient typically requires expert knowledge, yet the questionnaires were selected for each subject by persons who were not occupational health professionals.

Furthermore, the scope of questioning was broader than typically used by most physicians. For example, 72% of the questions in the IQ database are exposure- rather than disease-oriented, and 43% of the questions empirically used were related to exposures (many were generic questions such as age).

Clinical Implications

Physicians often do not "ask the right questions" even in likely occupational cases because they have had very limited training and experience in occupational–environmental medicine. [3–5] Milton et al [6] found occupationally relevant questions in only 10 of 67 medical records of patients deemed as likely candidates for occupational asthma (selected from an HMO population of 79,000). Primary and urgent care physicians asked the relevant questions in only 7% of likely cases.

An organized system for providing broad and multidisciplinary occupational health expertise on a widespread basis is needed. There is a shortage of professionals practicing occupational health. In the United States, only 16,000 physicians practice in this area, and only about 1500 are specialists. [7] The organization of health services is changing, making it less likely that an individual occupational health patient will see a physician with experience in this area. Through 24-hour coverage, many occupational health services are now provided by general medical groups. In addition, cost containment efforts are likely to decrease specialty referral.

Even when knowledge is available, time is often insufficient for a physician to obtain a complete occupational history. Lack of adequate time to interview the patient or visit the worksite was frequently identified as a major barrier to recognizing occupational disease in our survey of clinicians. The exhortation to "obtain a complete occupational history" is in conflict with the trend to increase "patient throughput" in clinical settings

Broad questions such as "What is your job?" or "Have you had occupational disease?" are unlikely to yield specific, useful information. Rather, questions that are most appropriate to the specific individual's health problem and the job characteristics are needed. Questions appropriate for a wheezing welder are very different from those for a coughing acrylic artist. This article describes a computer-based system for generating questionnaires with a high degree of case specificity

Computer systems can help overcome these problems. They can provide the necessary expertise when and where needed. An intelligent database system such as the one described in this report provides an efficient output questionnaire that is directly applicable in the routine patient care setting. Because an interviewer who is not a trained occupational health professional can administer the interview, relatively expensive physician time can be spared. Alternatively, the IQ system can generate a written questionnaire that the patient can complete. In the future, a patient can directly interact with the computer.

In addition, if IQ-like systems are integrated into routine care, they can provide information even if it is not explicitly sought; thus, they can serve as a significant motivating factor. Providing patients with information before a visit can help them raise topics in the clinical encounter. Such an approach has been used to foster discussion of clinical prevention in family practice [8] and by pharmaceutical manufacturers to educate patients about the availability of ethical (prescription) drugs. Computer-generated prompts, particularly if they are highly specific to the person, may also help the patient direct clinicians' attention to occupational aspects.

Expert systems (applications of artificial intelligence to specific knowledge domains) have been widely applied in other areas of medicine, but their application to occupational health has been much more limited. Computer prompts to alert clinicians of possible occupational disease have been used;[9] such techniques typically focus on a small number of classic sentinel health events. Other computer applications are designed to facilitate retrieval of knowledge from various reference sources. This requires that the clinician first be sufficiently knowledgeable and motivated to seek such information. Berman et al [10] recognized the limitations of commonly used literature search systems (eg, TOXLINE). They enhanced the search by following an expert system that used chemical structure information to look for closely related compounds. Their project, which focused on occupational asthma, showed significant potential of adding expertise (intelligence) to retrieval searches. Martin et al used computer methods to obtain and organize job histories;[11] they also expressed concern about the need for improved representation of information in the computer. [12] In addition, computer methods have been used to link clinical data (eg, death certificates, hospital data) with exposure. [13] Our group also previously developed an artificial intelligence system to facilitate recognizing occupational lung disease. [14]

Implications for Surveillance

Questionnaires are also used for occupational medical surveillance. The ability to aggregate data from various sources requires that the questions for all subjects be comparable in both wording and likelihood of being asked. Thus, there is usually a conflict between the need for specificity and the demands of consistency and general availability. Consistency is particularly difficult to achieve if surveillance is not limited to workers in a particular industry or plant. With the IQ approach, each subject is presented with a unique specific questionnaire, and consistency is facilitated because the question format and the question selection process are standardized.

Some workers may warrant more extensive interview than others; thus, questionnaire length may be adjusted for each case. For example, if a worker has asthma, many additional questions about work practices, exertion limitation, and medication use may be appropriate in addition to a single workplace specific question such as “Do you work with isocyanates?” Another worker in the same polyurethane plant may warrant questions about prior exposures if his or her previous job was that of an automobile painter. Thus, it is feasible to reconcile the clinician’s approach (seeking information in a nonstandardized, in-depth fashion) with that of the surveillance epidemiologist, who relies on a standard set of questions provided to all subjects.

A sequence of steps must be traversed to lead to occupational disease recognition from clinical settings (Fig. 2). In a particular industry and job, some workplaces have potential exposures, some workplaces have overexposure, and some of the overexposed workers develop symptoms. Some workers with symptoms may seek medical attention; of this group, some may be successful at achieving health care access, creating a pre-visit and post-visit status. Some workers will receive a diagnosis, and in some of these instances, the physician will report the disease to a surveillance system. Each of these eight temporal points represents an opportunity for intervention as well as a hurdle to overcome. Figure 2 shows the points at which information is collected and used under several approaches.

Fig. 2

The approach suggested in this ORDERS project moves intervention earlier than usually occurs. Intervention is applicable at the post-exposure, pre-visit, and post-visit/pre-diagnosis stages. Furthermore, intervention is capable of widespread implementation because it is not limited to a few conditions. It may be integrated into the general health care system, it does not depend on carefully selected clinicians, and it does not require extensive human expertise. Collected data may be uploaded to a central database without relying on physician reporting.

Although much health surveillance (eg, by analysis of workers' compensation reports) usually captures data only at the last stage if all prior stages actually occur, other methods have been used to facilitate surveillance. Occupational Safety and Health Administration–targeted inspections are based on step 1. Data utilization before seeking medical visits is based on asking patients directly for an opinion of work-relatedness (eg, from Social Security Disability System tapes [15] or the National Health Interview Survey). [16] Unfortunately, these techniques are extremely nonspecific, subjective, and limited in detail about the work exposures.

In some studies, human experts attempt exposure classification from the limited information available in cancer registries, etc. This method bypasses the need for physician diagnosis (collection at stage 6). Siemiatycki et al [17] and Stewart et al [2] applied human expert knowledge post hoc for malignancies to make educated guesses about exposures on the basis of job title, and Milton et al [6] applied expert knowledge to HMO data to determine whether the person might have been exposed to an agent that is irritating or sensitizing as a cause for occupational asthma. There have been some attempts to facilitate this with computer assistance. [18–20] These post hoc approaches are limited because of the paucity of available information. In addition, being conducted separately from the process of care precludes beneficial impact for the individual worker.

Some methods use data from the post-diagnosis stage rather than depending on physician reporting to surveillance systems. "Sentinel" SENSOR physicians in community practices are encouraged to report extensively directly to the project. This approach has been used for carpal tunnel syndrome and asthma in the SENSOR projects. [21] Some disease-specific surveillance systems rely on voluntary physician reporting (eg, PROPULSE in Quebec, [22] SWORD in England, [23–25] and a Finnish program. [26] These approaches seriously underreport disease; even mesothelioma is only reported half of the time. [27] Most do not allow determination of incidence and prevalence rates because the at-risk population is unknown and the sentinel physicians may not be representative of the community. SENSOR tried to overcome lack of detail in those who have reached stage 8 by follow-up telephone interviews to collect detailed information (eg, for occupational asthma and tuberculosis). [28] These systems still depend on recognition and reporting by physicians and are "labor intensive." Furthermore, they are narrow in scope, being limited to a small number of conditions. Even when diagnosed, many occupational diseases are not captured by workers' compensation data systems. For physician-diagnosed silicosis, for which work relationship is obvious, only 55% of cases involved claims. [27] Michigan SENSOR also showed poor reporting of asthma. [28]

Several studies have shown that the value of surveillance questionnaires can be significantly augmented by incorporation of more specific information than is typically employed in simple occupational questionnaires. Orlowski et al [29] noted the importance of identifying specific tasks rather than simply job title. Kromhout et al [30] examined the sources of variability in exposure estimates and found that information about production factors, indoor versus outdoor work, presence of local exhaust ventilation, and intermittency of task performance can add considerable information to job title alone. Thus, although job exposure matrices [31–33] can help convert job title into exposure data, much greater precision is available when more specific questions are asked.

Human experts are better than questionnaire or job exposure matrix approaches for detecting relevant exposures. [32,34,35] An IQ type system can help overcome the shortage of human expertise [36] and make it generally available.

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