The Computer and Clinical Decision-Support Systems in Primary Care

Thomas R. Taylor, MD, PhD
Seattle, Washington

For the primary care physician, the combination of an ongoing explosion of medical knowledge and an increasingly hostile malpractice liability climate makes access to accurate current clinical knowledge increasingly important. Modern medical undergraduate and postdoctoral education emphasizes the development of skills in accessing relevant knowledge over the memorization of an ever-increasing body of facts. For these reasons, more and more emphasis is being placed on making knowledge accessible to the clinician at the "point of decision."

The decision-support system is one of the most active approaches to this problem. Based on a monthly literature search on clinical decision making that I have run for the last 10 years, it is clear that new expert systems of one kind or another are now appearing in the literature at the rate of about one per month.

These new decision-support systems are almost exclusively in the procedural and laboratory areas of medical practice. Interest among physicians in the potential of computing has greatly increased in the last few years with the widespread availability of personal computers of dramatically increased power and versatility. The advent of well-engineered graphic interfaces has made numerical data much easier to present to the occasional user.

The article in this issue of the Journal by Potter and Ronan[1] describes CLINDERM, a computer software program for the differential diagnosis of diseases of the skin. The program will accept input of clinical descriptions of skin lesions made by clinicians. The number of different diseases in the knowledge base is 548, but because diseases can have different manifestations, the total number in the knowledge base is 1256. The user must pass through a maximum of nine decision nodes to reach a diagnosis. In the article a comparison was made between the program and an academic dermatologist using the same descriptive information as the computer program. The comparison used 129 cases from both hospital and ambulatory practice with 122 different diagnoses. Agreement between the dermatologist and the program was 95.3%. The program does not deal with nodular lesions, which demand a histological examination to make a reliable diagnosis. The classification algorithm uses branching Boolean logic and accesses a knowledge base derived from a classic dermatological text by Darier.[2] This base is augmented from current texts and purged of diseases now rarely seen. Attempts are made within the program to standardize terminology by providing definitions or synonyms where necessary. Teaching and prompting features are also included in the program.

As the authors state, this computer diagnosis system is human-aided, with the key clinical skill being the ability of the physician to translate clinical observations into the specific morphological language of the program. This system is an expert system in the sense that it has a *knowledge base* (derived from a classic text) and an *inference system* (branching Boolean logic) that receives data from the user and applies the knowledge base to produce advice (differential diagnosis), explanations, and teaching (definitions and synonyms), as well as lists of observations to be looked for when a particular diagnosis is being considered. The *man-computer interface* is text only, and it runs on standard IBM and compatible personal computers.

EXPERT SYSTEMS IN CLINICAL MEDICINE

Expert systems are computer programs capable of performing a task that normally requires the knowledge of an expert in that field. They date back to the early 1970s in, for example, the management of acid-base[3] and blood gas[4] disorders, and in digoxin dosage management planning.[5] Expert systems now cover a wide range of decision problems.[6–8] Two different approaches represent knowl-

Submitted November 21, 1989.

From the Department of Family Medicine, University of Washington, School of Medicine, Seattle, Washington. Requests for reprints should be addressed to Thomas R. Taylor, MD, Department of Family Medicine, Research Section, HQ-30, School of Medicine, University of Washington, Seattle, WA 98195.

edge in expert systems.[7] One (as in CLINDERM) is based on production rules (IF–THEN), which are applied to the knowledge base in an orderly manner to produce the solution to a diagnostic problem. The second approach is based on nodal networks of disease features linked together in a variety of patterns against which the new patient's features are compared by pattern matching. Some recent systems combine features of both approaches.[9] A second generation of expert systems now makes use of networks where causal pathophysiological information is embodied. This latter type provides particularly complex explanatory feedback.

Alternative inferential approaches in designing clinical decision-support systems include the use of clinical algorithms, probabilistic reasoning (usually based on Bayes' theorem), decision analysis, databank analysis for prognosis and therapy selection, and biodynamic modeling of specific biological systems (such as the respiratory system). Although these techniques have been applied to well-defined areas covering a limited set of hypotheses,[7] they cannot deal with the ill-structured problems so common in primary care practice. Unlike expert systems they lack conversational capabilities and, above all, the capacity to explain the basis for their decisions and recommendations in terms that are understandable to the clinician.

This latter capacity of explanatory power has been a major attraction of the expert systems that now dominate the field of clinical decision-support systems.[8] Applications specifically designed for the primary care field are rare.[10,11] Some have been developed in specialist populations and were tested for their usefulness in primary care settings.[12] The best-known expert system specifically designed for use in primary care setting, INTERNIST-1, was developed over a period of 15 years by a general internist, Jack D. Myers.[11] Based on his personal clinical experience as a consulting general internist, it contains information and management strategies covering about 600 diseases. One family physician in England has assembled an extensive library of the decision rules and related clinical knowledge that he normally uses in his clinical practice.[13,14] A computer consultation program to aid primary care physicians in the diagnosis of depression has been developed by Erdman et al.[15]

EVALUATION OF A SYSTEM FOR USE IN PRIMARY CARE SETTINGS

The evaluation of the CLINDERM system in this paper has been confined to the comparison of the classification-diagnostic performance of the system with an expert using the same data. This first step is necessary but insufficient and must, if favorable to the system, lead to a more broadly based clinical evaluation. High levels of predictive accuracy, as found with CLINDERM, are not unusual in early trials of decision-support systems.

In 1963 Kleinmuntz[20] showed that a series of decision rules elicited from competent clinical psychologists could be used to achieve a diagnostic accuracy of 91% for profiles of maladjusted students. Yet computer scoring of Minnesota Multiphasic Personality Inventory tests is not yet standard practice in clinical psychology. Similarly, in 1978 Wardle and Wardle[21] reviewed 27 studies of computer-assisted diagnoses, a large majority of which were in the 78% to 95% predictive accuracy range. So the performance characteristics of CLINDERM, while excellent, are not all that unusual. As far as I am aware, none of the systems reviewed by Wardle and Wardle have survived in clinical practice today. Corey,[16] in discussing a cardiac ischemia decision-support tool[12] that was evaluated in a primary care setting, has emphasized the three dimensions of formal evaluation to which such tools must be subjected, namely, (1) predictive accuracy, (2) usefulness, and (3) acceptability.

Most evaluations of decision-support systems are still limited to predictive accuracy. Thus the INTERNIST-1 system described above, when evaluated against cases from the *New England Journal of Medicine*, had a predictive accuracy of 65% to 75%.[11] A recent evaluation of the Quick Medical Reference (which is an extension/evolution of the INTERNIST 1 program), however, involved evaluation of all three dimensions of performance.[17]

One of the most enduring of the early decision-support systems is an abdominal pain diagnostic program based on Bayes' theorem[18] that dates back to the early 1970s and has undergone extensive trials over a number of years. An important early evaluation in 1972 found a 91.8% computer accuracy compared with 79.6% by clinicians.[18] In a prospective evaluation just reported[19] involving 6962 cases, however, the accuracy of the program fell to 42% to 59% compared with physicians at 65%. Here the cases were derived from three sites, including a large general hospital serving an urban and a rural population, a small inner-city hospital, and a large teaching hospital emergency department. With such a range of patients, the previously highly accurate program was not able to do better than 59%, worse than any of the physicians in the comparison. Indeed, it was suggested in this trial that many of the benefits in previous trials of the systems may have come from standardization of terminology and feedback to physicians rather than the decision-making power of the program.

So the obstacles to clinical implementation are not statistical or methodological. The future evaluation of clinical decision-support systems must be expanded to trials in the real world of clinical practice rather than in academic centers and must focus as much on integrating them into conventional practice patterns as on their predictive accuracy.

Given the excellent predictive performance characteristics of the CLINDERM decision-support system, what then are the obstacles to making such a system accessible to the primary care clinician?

OBSTACLES TO IMPLEMENTATION OF DECISION-SUPPORT SYSTEMS

Recent surveys of physicians' attitudes to decision-support systems[22,23] used random samples of both family physicians and primary care internists. These studies reveal the following serious concerns shared by all of the participants:

1. All physician subjects saw the computer as different from other technologies, such as magnetic resonance imaging scanners, in that it inserted a physical barrier between them and their patients with a resulting *loss of rapport with patients*. The physician, if he was to use the systems effectively, was perceived as seated behind a terminal interrogating the patient.

2. *Loss of clinical control* is seen by many observers to be the central barrier to acceptance of clinical decision-support systems. Clinical control is uppermost in the minds of physicians in an era of cost containment, litigation, and constant review of physicians' performance by outside bodies. The yielding of any clinical role to the computer is seen as an unacceptable concession to medical technology.

3. The above changes in the medical practice climate provoke a defensive response of *inertia* that professionals feel in the face of yet one more complexity in their professional lives.

4. While they did acknowledge the real problems of *information control* in conventional hard-copy medical charts, the computer is not seen as a remedy. The physicians acknowledged the need in contemporary medicine for access to the best available current information. But they made a critically important distinction between *information access and active decision support*. In other words, they may like easy access to computer-stored pharmacological information, but not directions on how to use it with individual patients.

5. Physicians also expressed a reluctance to accept that the computer could reliably assist physicians in the *complex decision tasks* that day-to-day clinical medicine entails. Lack of understanding of the clinical decision-making process[24] is a major obstacle to integrating such technologies into the real-world clinical context such as a busy primary care ambulatory practice. Many situations in primary care involve long-term management of chronic diseases with several comorbidities. This picture is frequently complicated by psychosocial factors critical to the process of care.[25]

6. The fear of *legal liability* was also a critically important issue to all of the physicians interviewed. Legally, decision-support systems occupy the same role in the exercise of judgment by physicians as textbooks, reference texts, and flow charts.[26] Other decision aids are second opinions, teamwork, and case conferences, which allow the pooling of knowledge and the sharing of responsibility for the outcome of an individual decision. The legal responsibility for any decision still rests with the clinician, who is expected to be discriminating about the sources of information that he or she uses.[27]

7. Most physicians thought that the future of clinical decision-support systems lay with the *younger generation of physicians*.

THE FUTURE OF CLINICAL DECISION-SUPPORT SYSTEMS IN PRIMARY CARE SETTINGS

Despite the many difficulties described above, the knowledge explosion and the demand for accurate and timely information in modern medicine make the search for effective decision-support systems for primary care physicians ever more important. The technological trends are toward most physicians having easy access to high-resolution workstations in their office or clinic that would make available relevant clinical data on their patients. These data would include images directly accessible from the archived digitized images in the radiologists' files. Digitized archived images are becoming the standard mode of storage in radiology departments. These workstations will allow access to laboratory results, including images of their patients' blood cells for comparisons to standard reference images, as well as nursing notes of vital functions. The advent of CD ROM videodisk technology will allow archiving of large numbers of such images in an easily accessible form. The CLINDERM system, with sample reference images of each of the features needed to classify the patient's skin condition, could be available alongside electronic textbooks, pharmacopeias, and up-to-date databases of drug interactions. The evolution of neural network technology holds the promise of decision-support systems that will expand their expertise by learning from experience. Decision-support technology is still in its infancy, and the obstacles to its implementation in the real world of clinical practice are still human ones rather than the limitations of technology.

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