TECHNIQUES FOR PHYSICIAN REVIEW OF PATIENT HISTORY DATA IN THE HELP COMPUTER SYSTEM

by

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I have read the thesis of Curtis Lee Anderson in its final form and have found that (1) its format, citations, and bibliographic style are consistent and acceptable; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the Supervisory Committee and is ready for submission to the Graduate School.

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ABSTRACT

The patient medical history is a necessary and critical tool for making diagnostic decisions. Recently the HELP hospital information system implemented a plan to collect a patient's history via a computer-directed, self-administered questionnaire. Because this method removed physicians from the history taking process, a scheme was devised to report the history and allow the physicians to directly edit patient responses. To determine the most efficient means of presenting this information, two review formats were made available. One format presented data via medical system or specialty. The other displayed data that generated computer-suggested diagnoses. The system was made available on a trial basis in two hospital rooms. Bedside terminals were provided to allow patients to take their own histories and allow physicians to review the history information on their patient rounds. Results showed that while patients overwhelmingly accepted the history taking process, physicians could not find the time to review the information through computer terminals. The physicians preferred to review the computer-acquired historical data by printed reports. Interviews were used to gather additional information from the participating physicians. This paper describes the history reporting/reviewing process and presents a basic understanding of the history taking system.
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CHAPTER 1

INTRODUCTION

Purpose

The recorded medical history is a necessary tool for making medical decisions. It is often the most productive source of diagnostic information (1). According to Mayne (2), patient histories are libraries of personal health recorded and edited by physicians which enable them to provide patients and society with beneficial medical decisions. This paper will present a scheme to remove physicians from directly taking the patient history yet allow them to review and edit important history information.

Until the advent of computers, physicians were required to spend a great deal of time taking patient histories (1). Time-pressured physicians have omitted key information (3, 4). Often this occurred because a physician only asked questions in his or her specialty or questions that would test a preconceived diagnosis (4). The manually collected, hand-written records were frequently illegible and unstructured. If a format for questioning was followed, it varied considerably among physicians. This lack of structure made it difficult for physicians to review the history at a later date (5).

It is the purpose of this thesis to demonstrate that effective, practical use of computers can eliminate these problems by: 1) asking patient-specific pertinent questions in a variety of special-
ties, 2) decreasing the amount of physician time needed for the history-taking process and, 3) reporting the history in a structured, easy to use form.

Computer systems designed to solve these problems began to appear as early as 1949 with the development of the Cornell Medical Index (6). The Cornell system collected historical information from patients on pencil and paper questionnaires. Responses were key-punched on data-processing cards and fed into the computer for the processing of diagnostic deductions. The set of questions presented was identical for each patient.

From the simple beginning established by the Cornell System, Warner Slack and co-workers (7) designed a history-taking system which varied in the questions asked each patient. Completed in 1966, the Slack system made the first attempt at using a computer to directly collect history data from the patient. Yes responses were followed by a series of specific qualifying questions. The data was then stored in a retrievable form for research and easy follow-up.

A system developed by Kiely (8) allowed physicians to communicate directly with a computer. This on-line system required the physician to enter the history through a series of screens. A light pen was used to indicate the key words in each screen needed for the history.

One of the first systems to follow a diagnostic line of logic was presented in 1969 by John Mayne of the Mayo Clinic (2). This program presented patients with broad screening questions in order to detect abnormalities which could help diagnose underlying diseases.
Significant responses were followed up with more specific questions. Like Kiely's program, a light pen was used to permit patients to enter their own histories.

In 1972, Homer Warner and associates published data on a system that greatly reduced the amount of time required to take a patient history (9). In their scheme, each patient was asked five key questions in ten categories. A positive response would elicit more specific questions needed to qualify the patient's answer. The number of questions asked was limited to the fifty basic questions, and to those needed to gather information necessary to confirm or eliminate the most probable diagnoses. Following a method pioneered by Gorry and Barnett (10), Warner determined which questions would evoke the diagnostic information by using sequential estimates of conditional probability to find the top contending diagnoses at a point in the processing. Questions that further qualified or disqualified a leading diagnosis were asked. Lists were kept to aid in the probability calculations as well as other controls to limit the number of questions asked. This system for limiting questions to only those needed for pertinent diagnoses reduced the average time required to take a self-administered history to fewer than ten minutes.

One of the innovative concepts in this scheme was the use of probability matrices matching history questions with diagnoses. Patient responses were scored against the matrix to determine what the most probable diagnosis would be for that response to that question. After several questions were answered, final probabilities were determined for all diagnoses on the matrix. By ranking the
diagnoses by probability, the computer could determine what diagnosis to concentrate the questioning on.

The results of this patient/disease specific history were presented to the physician in printed form. The report included the diagnoses with top probabilities and the respective history statements contributing to that probability.

These and other computerized history-taking systems (3, 11) developed have all lacked one important feature: the ability of physicians to edit erroneous patient responses in the computer-controlled questioning process. The patient history has always been an expression of the physician's interpretation and evaluation of a patient's response. In self-administered questionnaires there is no plan for physician interpretation. For this reason, a scheme must be devised to allow interpretation and possible editing of the self-administered history by the physician.

The necessity of such a feature was made evident in a study by Chamberlain (12). He found that pregnant women often give their physician false answers to history questions. Another study found that when physicians asked the same history question twice, one in five patients changed their response from "yes" to "no" (13). This inconsistency mandates the development of a system that not only displays the data but also allows a physician to edit or change the patient's response.

The purpose of this paper is to introduce a method for reviewing and reporting a patient's recorded history. This procedure allows the physician to review and change any response he or she feels
incorrectly reflects the patient's condition. This review method is part of the HELP, (Health Evaluation through Logical Processing) computer system developed by the Medical Biophysics and Computing Department at the University of Utah. The system is presently in use at LDS Hospital in Salt Lake City, Utah.

The review procedure is part of a larger system that captures the patient pulmonary history at a bedside terminal. It was designed around the philosophy that physicians should be the receivers, not givers of medical information. This self-administered method frees the physician to pursue other clinical tasks. Only six key questions are asked of each patient. Responses are processed to generate more specific, qualifying questions. Questioning continues until diagnoses having significant probability of explaining the patient's symptoms are found. The review program allows a physician to review, interpret and change, if necessary, the self-administered patient history. The pulmonary history data are presented in various formats, allowing the physician to review by diagnosis or body system. In this way, only data of interest are introduced and valuable time is saved. A more definitive description of the review program and HELP system will be presented later in this paper.
Review of medical decision-making systems

Over the past twenty years, several computer systems have been developed to aid physicians in making medical decisions. Most of these were dedicated to performing specific tasks. Only a few systems were designed with the capability to make decisions over a broad range of medicine. This section will review the more comprehensive systems that were capable of making decisions over a wide area of medicine or had the capability to be expanded into that capacity.

Early decision-making systems made diagnostic inferences from the information at hand. The system created by Gorry and Barnett (10) went one step further than the rest. They concerned their research not only with diagnostic inference, but with determining what tests could further specify the diagnosis. Reasoning that physicians rarely have enough initial information to make a satisfactory diagnosis, Gorry and Barnett devised a scheme to gather the additionally needed information.

Initial patient data was processed through Bayesian probability calculations (14) to formulate a preliminary collection of possible diagnoses. These primary decisions were followed up with requests for tests that could increase or decrease their diagnostic probability. To reduce the number of tests required by the system, Gorry and Barnett weighed each test according to cost, expected outcome, and relative importance in avoiding a misdiagnosis. If the cost for a test was high and the outcome was expected to be of little diagnostic importance, the test would not be asked for. Yet if a test was particularly important in avoiding a misdiagnosis, it might be
requested despite a high cost. The tests ranged from simple questions regarding patient age to extensive laboratory results.

As the test information accumulated, results were placed in Bayes equations to update diagnostic probabilities. This sequential calculation of probabilities allowed the system to alter testing strategy during processing. If a diagnostic probability was lowered below some threshold level, tests to further qualify or disqualify that diagnosis were no longer considered. Alternately, a diagnosis with a very high probability might suspend further processing because a likely explanation for the patient's problem had been found. This scheme proved to be an important guide for the more contemporary computer systems which used sequential processing to analyze data as it was received.

In the early 1970s, Lawrence Weed of the University of Vermont developed the Problem-oriented Medical Information System or PROMIS (4). In this system, patient problems were used as the focal point for maintaining and analyzing decision-making information. After establishing a data base, the computer program formulated a list of all the patient's problems, made initial plans for individual problems and finally, maintained progress notes on each problem.

The PROMIS scheme was the first to use computers to manage a broad range of patient information. The data base contained the chief complaint, patient profile, present illness or illnesses, past medical history (including significant negatives), a systems review, physical exam information, baseline lab results, and a concise description of the patient's way of life.
From this extensive data base, a patient-specific problem list could be generated. Possible components included social, psychiatric and demographic problems, past or present medical diagnoses, unresolved medical problems of the past and notification of an incomplete data base. Each problem was given a general conclusion which was followed by a major recommendation for its resolution. The recommendation included plans for diagnosis and treatment as well as requests for additional data.

The progress notes were entered and stored in a clear, precise format that mimicked the logic of problem-oriented medical thinking. They provided the physician with important feedback and a way to preserve and measure the quality of medical information and decisions. Weed incorporated the patient's way of life and entire range of problems to generate a credible overall diagnosis and treatment. A computer greatly enhanced the ability of the physicians to manage this much information. The only problem with Weed's approach was the large amount of physician time required to communicate this amount of information to the computer. A system was needed that reduced this important parameter.

The MYCIN system developed by Edward Shortliffe (15) was the precursor to present rule-based medical consultation/decision systems. The knowledge base for MYCIN was comprised of therapeutic decision rules. Each rule contained a premise and an action or conclusion. If the precondition was found to be true, then action was taken or a conclusion made. If it was false, then the rule was rejected. And if the condition was found to be missing, the user was
queried for the absent data.

MYCIN was developed to advise physicians on antimicrobial therapies for patients with bacterial infections before cultured lab results were known. The process began when the system requested, from the physician, data concerning basic patient information and organismal traits such as morphology and type of stain used. These initial data permitted the computer to generate a list of possible organisms responsible for the infection. With these data in mind, the MYCIN scheme asked physicians about patient allergies, infection sites and other pertinent information to determine a recommended therapy. By giving the physician an idea of possible causative organisms and treatments, MYCIN enabled therapy to begin without waiting for bacteria cultures to mature. MYCIN correctly identified the causative bacterium or bacteria in 75% of the cases studied. Misses were most often due to a lack of decision rules for that organism or treatment.

To enhance the acceptance of their system, MYCIN researchers incorporated, in an interactive mode, procedures allowing physicians to ask why a certain rule was being pursued. This ability to explain recommendations for organisms and therapies was viewed as a necessary function by physicians who used the system. In addition to the "why" mode, medical experts using the system could correct and/or augment rules in the knowledge base.

MYCIN appeared closer than any other large decision-making system to being accepted by physicians. Yet few researchers had attempted to find out how physicians felt about computers and what
types of computer system they would accept.

In 1981, a study conducted by Teacher and Shortliffe at Stanford University (16) revealed several interesting views physicians have concerning the use of computers in a consultation setting. They found that computers would be accepted as a clinical aid but not as a diagnostic replacement for physicians. In addition, the approval of a medical computer system depended upon its ability to simplify the delivery and improve the quality of patient care. The physicians wanted a system that would function like a human consultant and be a tool to aid in patient management decisions. Physicians polled noted that the system should not give information in a dogmatic manner nor should it consume additional physician time. They also requested that it be able to justify and explain its advice and decisions.

INTERNIST (17) is an experimental computer-based diagnostic consultant developed at the University of Pittsburgh. It is capable of making multiple and complex diagnoses in internal medicine. Like a physician, the computer system constructs specific differential diagnoses for a problem area then narrows down the set of possible diagnoses to a collection of competing hypotheses. Finally, it uses heuristic principles to resolve each differential hypothesis and determines the most likely diagnosis.

The INTERNIST knowledge base is designed to give INTERNIST the ability of constructing and resolving differential diagnoses. The building block for this knowledge base is the individual disease. Each disease has a profile consisting of demographic information, historical items, symptoms, physical signs, and lab abnormalities.
The list of manifestations for each disease is inverted to get a list of differential diagnoses for individual findings.

Coupled with each of these manifestations is an evoking strength and a frequency. The evoking strength is a measure of how strongly the physician feels the disease is the cause of this manifestation. The frequency is an estimate of how often patients with the disease display this particular manifestation or symptom.

Processing in the INTERNIST system involves two basic procedures: formation of problem areas and concluding diagnoses within the problem areas. The first step in this process is the entry of initial patient findings. Each positive finding generates a complete differential diagnosis for that finding. The diagnosis is retrieved from the inverted disease profiles in the knowledge base. This gives each finding or manifestation a "disease hypothesis." After the initial data is entered, each hypothesis is scored and sorted in descending order. Scores are determined by the presence or absence of a manifestation required in the hypothesis. Interrelated diseases are linked so that one hypothesis can boost the score of a related hypothesis. Scores that fall below a threshold are discarded. From the list of descending hypotheses, a problem area is created that best reflects the area of patient complaint. This area includes the hypothesis with the highest score. If there is only one disease hypothesis in the problem area, it is concluded to be the patient's diagnosis. If more hypotheses are in the problem area, additional questions are asked to exclude some hypotheses or support a single most likely hypothesis. Disease hypotheses are scored again after
each group of questions is answered. Questioning and scoring continues until one hypothesis has a score much higher than the competing hypotheses or only one hypothesis remains in the problem area. If a single diagnostic conclusion cannot be reached, the computer will present, in descending order, a list of all hypotheses in the top problem area.

INTERNIST processes seventy to seventy-five percent of the most common ailments in internal medicine. In 1982 it could accurately diagnose fifty-eight percent of the cases presented to it. Still in use today, INTERNIST functions mainly as an educational tool.

Perhaps the greatest drawback to the INTERNIST system, as well as most other computerized diagnostic systems, is the great amount of physician time required to input the information necessary to make medical decisions. Another downfall of INTERNIST is the incorporation of physician bias by arbitrarily weighing the most likely diagnosis for a finding.

The SPHINX system, designed by M. Fieschi (18), incorporates many of the achievements of previous diagnostic systems. It is a rule-based system that receives information from the patient and from requests generated by the system itself. Hypotheses are established which are confirmed or disconfirmed by system-requested examinations.

The rules comprising the knowledge base are written by an expert. The knowledge base itself is a tree-like structure. Subtrees correspond to pathological units or to a disease's clinical condition. A diagnosis is made when the pattern of a patient's data matches that of a tree-like medical decision. The tree structure of
the knowledge base allows for easy expansion in a decision area.

Like other diagnostic systems, SPHINX uses heuristic features to facilitate diagnostic processing. The presence of a symptom may suggest one hypothesis is more likely than another. Alternately the absence of the symptom may cause the same diagnostic hypothesis to be rejected. One of the innovative concepts of SPHINX is placing more power in this rejection mode of diagnostic processing.

Fieschi's system also uses examination cost and successful branching rate in determining what diagnosis should be given the most consideration. Diagnoses that are more common than competitors and that require low-cost tests for final identification are more likely to be chosen for diagnostic consideration.

SPHINX processing begins when the chief complaint is received from the patient. From this information a set of possible syndromes is established. Using heuristics, the system asks for complementary investigations to help identify suggested diseases. When all diagnostic lines have been satisfied, processing ceases.

In 1982, the SPHINX system could only diagnose causes of epigastric pain. The data base was large enough to process about eighty-five percent of the cases presented to it. Of these, eighty-eight percent would be diagnosed correctly. The diagnoses were not presented to the patient's attending physician.

An overview of major (and some minor) computerized medical decision-making systems has been presented. All of these systems have strengths and weaknesses. They were delivered in chronological order so the reader could envision the natural progression toward
more sophisticated systems in use today. One of these systems, HELP, has seen more clinical use than all of the other systems combined. While other decision systems were concentrating on achieving "artificial intelligence," the developers of HELP were working on practical solutions to clinical problems. The HELP system has been omitted thus far because it is an important part of the history review system to be presented in this paper. The HELP system will be described in some detail in the next section.

The HELP system - a general overview

The HELP, Health Evaluation through Logical Processing, System runs on a 6 CPU Tandem mainframe computer. In addition to the virtual memory of the central processing units, over 770 million bytes of disc memory are available (19). The Tandem computer communicates with medical and research personnel through 362 terminals and 73 serial printers. The mainframe computer maintains dual copies of executable programs and patient data on disc at all times. This reduces down time and allows system managers to run clinical and research users simultaneously. During hours of peak clinical demand, research use can be suspended to insure quick response time for physicians and nurses.

HELP is based at the tertiary care, 550 bed LDS Hospital in Salt Lake City, Utah. Located near the University of Utah School of Medicine, the hospital serves as a primary teaching center for medical students and resident physicians. The HELP System was designed to meet these educational and teaching needs as well as the clinical, administrative and research needs of the hospital (20).
As an information system, HELP provides medical personnel with patient data concerning laboratory results (most recent as well as entire hospital stay), hospital-administered drugs, allergies, demographic data, surgical information, respiratory therapy notes, cardiac volumes and pressures, pulmonary function information, admitting diagnosis, radiological findings, blood type, cardiac arrhythmia alerts for patients in critical care wards, past hospital stays, and computer-generated hypotheses concerning possible diagnoses. These data are available at all nursing stations and in areas of high demand such as the hospital library and physician lounge. Several outlets are located in private offices in the Physician Office Building adjacent to the hospital.

To support the computer-assisted medical decisions required to accumulate and disseminate such a wide range of knowledge, HELP employs a data base generated from patient information sources throughout the hospital. These include admitting, admission screening, emergency room, clinical laboratory, pulmonary laboratory, cardiac catheterization laboratory, ECGs, radiology, pharmacy, nursing stations and others. Most of the data is gathered automatically from medical instruments through digital or analog interfaces. Qualitative data such as vital signs can be included by data entry technicians. Provisions for the entry of the medical history and physical exam findings have only recently been implemented. These are supplied by the patient and attending physician respectively. In areas where the input of data is especially heavy, minicomputers acquire and preprocess the data before sending it to the mainframe
computer en masse (19, 21, 22).

The data collected and stored by the computer is used not only in managing patient information but in addressing administrative needs as well. The system performs such vital functions as automatic billing and room/division patient load management. Personnel management programs allow the nursing wards to match nursing personnel with patient load.

The HELP data base is comprised of a long-term file containing an abbreviated version of demographic and clinical data (considered to be useful if a patient were readmitted), and a short-term comprehensive file containing all the data a patient acquires during the current hospitalization (19). Individual data items in these files are stored with a time parameter so time relationships can be incorporated into the decision-making process (22).

The data are stored in a coded form to facilitate retrieval and analysis. Data codes are defined in a hierarchical structure by a computer-based dictionary termed PTXT. The PTXT definition contains a description of medical terms and the corresponding numerical codes. It is these codes that are stored and processed by the computer. The textual representation of these codes is what the user of the system sees. In addition to codes and corresponding text, the dictionary contains keywords, billing charges and units of measurement where they are required (19, 22).

Organizing these codes into a hierarchical structure allows the data to be accessed by general or specific codes. The hierarchy is arranged into classes representing separate clinical or research
areas. These data class trees are further broken down according to naturally occurring divisions within the data class (Fig. 1). Examples of data classes include patient identification information, chemistry laboratory data, medical records, blood bank data, X-ray data, dietary information, history/physical exam, HELP medical decisions and others (19, 22).

To add an item of data to the dictionary, the user must first determine where in the hierarchy it will be best defined. For example, a serum potassium result would belong in the Chemistry Laboratory data class. The user defines the code and adds the medical message which will be represented by the newly defined code. The text is what will be displayed as output to the medical personnel.

Keywords, which are used for easy code identification and acquisition when an expert is constructing search items in medical decision algorithms, are also defined and associated with the code at this time. In this manner, all necessary medical terms and descriptors used in data management and decision-making can be accessed easily and swiftly (19).

Like other knowledge base systems, HELP incorporates rules created by experts in various medical fields to manage computer-assisted medical decision making. The HELP knowledge base is formed around medical decision algorithms called sectors. These sectors use deterministic "if... then..." logic and/or probabilistic logic (based upon Bayes' equation (14)) when making medical decisions. Often the two approaches are used cooperatively (19, 22). (Note: see Appendix A for a more detailed description of these two approaches.)
Figure 1. Hierarchical data base structure. If expanded to include type and level, the PTXT (data dictionary) code for the history question "Is the sputum yellow, green or brown?" would be:

<table>
<thead>
<tr>
<th>Data Class</th>
<th>Type</th>
<th>Field Code</th>
<th>Level</th>
<th>Noun</th>
<th>Adjective</th>
<th>Adverb</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>1</td>
<td>120</td>
<td>3</td>
<td>10</td>
<td>22</td>
<td>4</td>
</tr>
</tbody>
</table>
A HELP sector is a collection of statements amassed by a medical expert to evaluate patient-specific data and make medical decisions representing that data. They are written in a language which utilizes medical terminology and organization. The "naturalness" of the language eases communication problems with physicians who have little computer knowledge. Experts compose sectors only in their field of medical specialty. For example, physicians specializing in internal medicine could write sectors dealing with pulmonary disorders. The natural language of HELP enables these experts to describe their decision-making process in medical terminology which mimics the logical ordering used in everyday practice. The decision information generated by sectors is based upon searches in the patient files for data items asked for within the sectors. This searching is managed by the HELP driver program. If the sector being processed looks for information produced by another sector, the driver will run that sector too. Additionally, authors may incorporate logical, statistical or mathematical constructs to analyze data searched for in the sector. Time constraints can be used to limit searches to specific time frames (19, 21, 22). Elements of a sector might include:

1 - A message or title which is displayed when the sector criteria have been satisfied.
2 - Requests to search for and retrieve specific patient data items needed to confirm or disconfirm the decision.
3 - A list of logical and/or arithmetic statements used to evaluate the retrieved patient data.
4 - Bayesian probability calculations for quantifying infor-
mation as it is received.

5 - References to other sectors which may be related to the current decision (19).

Refer to Appendix B for a representative HELP sector.

After a sector is written, it is possible to test the new rule using actual patient data without endangering the patient's record. If the algorithm is found to be unsound, the author can easily edit or change the faulty portion without rewriting the entire sector. The author is also responsible for updating decisions as new breakthroughs occur in medicine and technology (19, 21, 22).

Sectors are designed in a modular fashion to facilitate processing speed and growth. They are organized into groups or "blocks" dealing in particular medical areas (21). This aspect allows a complex system of rules to be built for each medical specialty (22). For example, sectors dealing with pharmacy alerts would be organized into a "stand alone" block of rules specific to pharmacy alerts. When they are processed, sectors can be evaluated individually, as related decisions, in blocks or in groups of related blocks.

In an information setting, HELP uses sectors to make qualified statements about a patient's medical record. HELP sectors process prespecified data to inform health professionals about important conditions such as arrhythmias occurring in coronary care patients, pulmonary function/blood gas conclusions, pharmacy alerts to drug-drug interactions and allergy alerts (19).

In recent years it has become apparent that computers are not only valuable sources of information but they are important diagnos-
tic tools as well (23). This is recognized because it is impossible for physicians to be completely unbiased and knowledgeable in their specialty (23). HELP enters the field of computer-assisted medical diagnostics via decision-oriented HELP sectors. The designers of these sectors focus their attention on decisions commonly overlooked in routine medical practice to examine appropriate diagnoses even when the corresponding disease is not apparent (21).

Perhaps the most important source of diagnostic information lies in qualitative data such as patient history and physical findings. To acquire these data, HELP uses a "cognitive modeling" process. There are two main components of this method: data-driven diagnostic testing and Decision-driven Data Acquisition (DDA).

In data-driven hypothesis testing, one or more items of data deemed to be important parameters of a diagnosis will be identified. These items evoke consideration of the diagnosis when it is stored in the computer. In HELP, these diagnosis-driving items are identified by the expert writing a diagnostic algorithm (sector). The sector is evaluated every time one of its diagnosis-driving data items is added to the patient's record (19, 21, 22). For example, a sector that makes decisions about bacterial bronchitis might identify an item concerned with recent coughing. When this item is added to a patient's record, the sector concerning bacterial bronchitis will be processed. Other sectors, such as pneumonia, which identify recent cough as a data-driving item, will also be evaluated. In this manner all sectors using recent cough as a prime element in their decision making process will be considered (21). A representation of the
bacterial bronchitis sector can be found in Appendix B.

Complementary to the data-driven tool described above is a decision-driven data acquisition tool, the ASK function. ASK refers to search items in a sector that must be present in the patient's file before the sector's evaluation can be completed. If the data item is not in the patient's file, it will be "asked for" from the attending physician, nurse or patient. The items to be asked for and the expected data sources are specified by the expert writing the sector. The ASK process operates only when the referenced data are not in the patient's file. As a decision-driven data acquisitioning tool, data are "asked for" only to explore a specific decision (19, 21, 22). A sector using decision-driven data acquisition via the ASK function appears in Appendix B.

At the center of this complex system is the query driver program. It collects the ASK requested data, formats these requests and presents them to be answered. If the person to receive the request is currently using the computer, the data request is presented directly to them. If the person is not at the terminal when the request is generated, the question will be stored until they sign onto the computer. After the request(s) have been responded to, the newly acquired data are stored and the query driver reruns the requesting sector. If any of the new data are identified as data-driver items in additional sectors, these sectors will also be processed. If there are ASK items in these sectors, more data requests will be generated. The cycle of acquiring data, running data-driven decision hypotheses, requesting pertinent/unstored information, storing new
data and generating new data-driven hypotheses continues until adequate data are present in the patient record to resolve all hypotheses under consideration (21, 22). The specific application of the data and ask driver modes in acquiring historical data will be addressed later.

The bedside medical decision-making system

In order to improve the accuracy of computer-assisted medical diagnoses, researchers recently added the patient medical history to the HELP database. Inasmuch as HELP is a system which attempts to make physicians the receivers, not givers, of medical information, it was decided to use patients as the source of these data. A method was designed that allowed patients to comfortably interact with a computer from their hospital beds. (Note: the old method used to obtain patient histories, via a sequential Bayesian approach (9), had been discontinued because of hardware changes.)

To prevent the patient from becoming overwhelmed with computer-generated history questions, HELP designers blend cognitive modeling with Bayesian scoring algorithms to determine which questions are most appropriate for a particular patient. This scheme utilizes the previously described data-driver and ASK modes. The data-driver assures evaluation of HELP sectors which use important history data in their decision-making process. The ASK mode queries the specific data source (in this case the patient) for pertinent information needed to make a medical decision or diagnosis. In the bedside history-taking process the data-driver and ASK modes combine to ask (ASK mode) patients questions which refer to decisions generated (data-
driver) by the patient’s responses. In this way, only decisions applicable to the specific patient are considered. Ideally, just enough questions are asked to fully document the patient’s history (as it relates to the current problem(s)), without overburdening the patient with unnecessary questioning. Hence, each history question is asked only if it addresses a problem specific to the current patient.

To initiate the new system of history data acquisition, general internal medicine patients with pulmonary disorders were chosen as a pilot group. Bedside terminals were provided in a few select rooms normally occupied by this group of patients.

When a pulmonary patient is admitted and comfortably settled into one of these rooms, a nurse will enter the patient’s identification number into the bedside terminal. The microcomputer now will dedicate all processing at that terminal to the patient currently residing in the bed. The nurse then directs the computer to begin the history questioning process and turns the terminal over to the patient who can begin answering questions at his or her own pace.

The first set of questions are key questions asked of all pulmonary patients using the bedside system. All questions are answered by pressing two special keys on the terminal keyboard marked “yes” and “no.” A third key can re-ask previously asked questions (on the current screen) if the patient recognizes a question was answered incorrectly. Questions are designed to remove the need for a “maybe” or “not sure” response. If the patient answers positively to a key question, the stored question and response will data-drive HELP sec-
tors using that question as a data-driving item. As these sectors are evaluated, additional history questions (ASK items) that exist in the newly evaluated sectors will be presented by the query driver. As further questions are responded to in a positive manner, more decision hypotheses and corresponding ASK questions will be processed. Alternately, if all key questions in the first screen are responded to in a negative fashion, a second and final screen of key questions will be presented. There are six key questions in the pulmonary history-taking system:

1. Have you had a fever with this illness?
2. Have you ever had asthma?
3. Have you been short of breath with this illness?
4. Have you had a cough with this illness?
5. Have you had recent chest pain?
6. Have you had wheezing with this illness?

Many of the questions processed by the query driver belong to sectors which use a Bayesian probability scoring algorithm. Decision hypotheses (sectors) are scored and ranked from least likely to most likely diagnoses. Using this information, the query driver determines from the current list of ASK-generated history questions those which are most likely to affect the probabilities of the topmost diagnoses. These questions will be asked before others which affect only lower probability decisions. As new batteries of questions are answered and stored, the sectors are reevaluated to calculate new probabilities and generate new questions. The cycle of storing new data and considering related decision hypotheses continues until the
patient has been queried for all the data relevant to his or her problem(s) or the sum of the probabilities of sectors with unasked questions drops below five percent.

Another control in the history questioning process makes use of the hierarchical structure of the data base. General, higher-level questions are asked before more specific, low-level questions can be addressed. For example, if a sector is driven that asks a question about the existence of purulent sputum, the parent question establishing a cough with the illness (Fig. 1) must be asked and answered positively before the more specific question can be presented. Answering yes to a general question will elicit more specific, subhierarchical questions. A no response will effectively store a no value for all questions existing below the higher level question. If a sector looks for a sublevel question whose parent was stored as a "no," it will recognize the answer to that question as no even though the question was never explicitly asked. These algorithms and the hierarchical structure of the data dictionary prevent the system from asking the patient detailed questions whose answers can be inferred from more general questions (21).

Another heuristic restricts questioning to questions that will do the most to resolve the diagnoses under consideration. The procedure involves determining which of the remaining questions to be asked will affect the diagnostic probabilities to the greatest degree. Each question remaining to be asked is weighted by the sum of the probabilities of the diagnoses which use it in their diagnostic reasoning. Questions with the greatest probability sum are asked
first. It is therefore possible for a question of mediocre impor-
tance in several diagnoses to be asked before a question of great
importance in a single diagnosis. This strategy has been found to
select questioning sequences which lead to rapid convergence on the
most appropriate diagnosis.

The following points should be noted about the history-taking
system:

1 - A cognitive model generates patient-specific hypotheses.
2 - Bayesian scoring algorithms allow estimates of the relative
likelihood of the hypothesis.
3 - Several "ad hoc" control structures limit the pursuit of un-
likely hypotheses.

To meet the processing demands of the history acquisition
scheme, HELP researchers purchased a Charles River Data Systems
Universe 68 microcomputer. This processor is dedicated to a specific
hospital room or group of rooms. The microcomputer is powered by a
Motorola 68000 cpu. Two megabytes of random access memory and 30
megabytes of memory on Winchester disc insure a rapid response time.
The Charles River microcomputer can handle up to twelve peripheral
ports. Communication with the bedside terminal is through a direct
line. The terminal is mounted on a wheeled cart to facilitate stor-
age in an uncongested area near the patient's bed. The Charles River
microcomputer uses a UNOS operating system and can be programmed in
the "C" computer language. All programs used at the patient bedside
have been written in this language.

Interfacing the Tandem and Charles River computers is accomp-
lished through a special communications package. This package translates data and HELP sectors as they are exchanged between the two systems. Information is transferred on a direct line at 9200 baud. Only sectors dealing with history and physical examinations are stored in the microcomputer. This allows the data to be stored in an unpacked, ready-to-process form. Patient identification and demographic data are sent down by the Tandem when a new patient is admitted into a room with a bedside terminal. The Charles River computer sends up history and physical examination data to the patient's record on the Tandem shortly after the data acquisition processes are completed.

The history review system at LDS Hospital

When the bedside history-taking system was developed, physicians and designers understood the need (as described previously) for physicians to be able to review and possibly edit the computer administered history questionnaire. A review program was needed to bring the patient-specific history to the physician in an acceptable format. The review process must also allow the physician to change inaccurate patient responses.

To keep track of these changes each history question was given a value. These values informed researchers not only if the patient had answered yes or no to a question, but also if the attending physician had reviewed the particular question. A different value was assessed if the patient response was changed in addition to being reviewed (Fig. 2).

Like other HELP programs, the review program needed to give
Figure 2. Value matrix. This figure shows the possible values for history questions. Note that all yes values are greater than or equal to 5, whereas all no values are less than or equal to 4. This facilitates probabilistic processing in HELP sectors (Appendix B). Note also that for values 3 and 8, the value change reflects that the physician has reviewed, not changed, the patient's response.
physicians a maximum amount of information with a minimum of input. The process should also be easy to understand and flow in a logical fashion. Working within these and other restrictions, the history review and editing program was developed. A scenario of the process begins in the following paragraph.

After a patient completes the bedside history-taking process, the physician may, at his or her convenience, sign onto the computer and enter a key word or letter to access "privileged" data manipulation programs. The history review/editing program may be selected at that time. (Process flow in the history review/editing program is graphically depicted in Appendix C.)

The first screen presented in the review process contains various functions available and a corresponding index (Fig. 3). If the user wishes to review the patient's history via a physiological system, option #1 will be selected. The next screen to appear for this format will be a list of sixteen possible categories (Fig. 4). More than one category can be selected if the user separates indices with a space. In the succeeding step the program determines what field codes (a level in the data base hierarchy immediately under the data class category), are associated with the selected medical system category. Using the hierarchy of the data base all history questions under these field codes are searched for and retrieved from the patient record. In the following screen these questions, along with the patient response and a corresponding index, are presented in medical jargon which is familiar to physicians (Fig. 5). The hierarchical structure of the data base allows the history taking review system
1. Questions referring to specific medical systems.
2. Questions that generate a specific diagnosis.
3. List top 5 HELP decisions at your terminal.
4. Printout of the top 5 HELP decisions and history questions. (Type 's' to STOP.)

Figure 3. Review program option menu.

Select the medical area you would like to review:
1. Constitutional
2. Integument
3. Head, eyes, ears, nose, throat, neck
4. Cardiopulmonary
5. Gastrointestinal, hemorrhoids, hernia
6. Genital-urinary
7. OB/GYN, breasts
8. Extremities, joints, back
9. Adenopathy
10. Neurology
11. Psychiatry
12. Past medical history
13. Medications, allergies
14. Family history
15. Social/Occupational/Travel history
16. Misc. history

Figure 4. Medical system by physiological category.

The patient responded in the following way to history questions:
#Y 1. FEVER
#Y 2. CHILLS
N 3. WEIGHT LOSS
N 4. EASY FATIGIBILITY
N 5. NIGHT SWEATS
N 6. LONG TERM WEIGHT LOSS

Figure 5. History questions for constitutional category.
to ask a patient history questions in easy to understand terms yet it reports the questions to physicians in natural medical language. For a comparison of these two formats, see Appendix D.

The review program lists yes questions first. These are followed by questions with a negative response. In the medical system format up to fifteen questions can be displayed on the terminal at one time. The user is allowed to choose one or more indices, which correspond to the question response deemed to be invalid, and enter them into the computer. Multiple indices are separated by a space. The program then processes these changes and stores them in the patient record. The time of the change is stored with the question as the new time parameter. Old history questions are deleted to avoid duplication. Disregarding any changes, all displayed history questions are deleted and restored with the new time parameter and a new value (Fig. 2). If a response change was made by the user/physician, a flag is set to indicate that the HELP sector evaluation program should be processed to generate a possibly new set of decisions based on the response change(s). This occurs only after the newly changed history data have been stored in the patient record. Only sectors currently stored in the patient file are reevaluated by this call to the HELP processor. At the completion of this process the beginning screen is displayed again along with the current top five HELP decisions/diagnoses (Fig. 6).

If the user elects to review history questions that are used as search items in HELP sectors to generate HELP decisions, option #2 will be selected. The succeeding terminal display (Fig. 7) will con-
CURRENT 5 MOST PROBABLE HELP DECISIONS

1.00 CHRONIC BRONCHITIS (HISTORY)
0.86 PNEUMONIA (HISTORY)
0.18 ACUTE BACTERIAL BRONCHITIS (HISTORY)
0.12 MYCOPLASMA PNEUMONIA (HISTORY)
0.02 REACTIVE AIRWAY DISEASE (ASTHMA) (HISTORY)

1. Questions referring to specific medical systems.
2. Questions that generate a specific diagnosis.
3. List top 5 HELP decisions at your terminal.
4. Printout of the top 5 HELP decisions and history questions.
(Type 's' to STOP.)

Figure 6. HELP diagnoses and option menu.

1. 1.00 CHRONIC BRONCHITIS (HISTORY)
2. 0.86 PNEUMONIA (HISTORY)
3. 0.18 ACUTE BACTERIAL BRONCHITIS (HISTORY)
4. 0.12 MYCOPLASMA PNEUMONIA (HISTORY)
5. 0.02 REACTIVE AIRWAY DISEASE (ASTHMA) (HISTORY)

Select the index corresponding to the decision you would like to review. Please select only one index.

Figure 7. HELP diagnoses option list.
tain the patient's top five HELP diagnoses and an index. The physi-
cian may then select any diagnosis he or she would like to review.
The program searches through the selected HELP sector to find all
search items of a historical nature. The retrieved question codes
are duplicated and stored in the report program. A search is then
conducted in the patient's file to see if any of these codes
(questions) have been stored. If a match is found, the code is
flagged and stored in an array for presentation to the user. After
the data base search has been completed the matched history question
codes are sorted and presented, yes questions first, to the user
(Fig. 8). In the diagnostic format only twelve questions can be
displayed at one time. Similar to the medical system format, a cor-
responding index is used to identify displayed history questions.
And like the system format, changes induce the HELP processor to re-
evaluate the currently stored sectors. The top five diagnoses and
beginning screen is displayed again. If a response change was made
it is possible that the list of top five HELP decisions will also be
changed.

As an example, envision a patient who has responded to the
computer-generated history questionnaire in a way to induce the
following top five computer-generated diagnoses to occur:

0.99 CHRONIC BRONCHITIS
0.86 PNEUMONIA
0.18 ACUTE BACTERIAL BRONCHITIS
0.12 MYCOPLASMA PNEUMONIA
0.02 REACTIVE AIRWAY DISEASE (ASTHMA)
History suggests the following differential diagnosis:

0.18 ACUTE BACTERIAL BRONCHITIS (HISTORY)
--- because the patient answered:
YES to 1. FEVER
YES to 2. RECENT COUGH
YES to 3. DYSPNEA
YES to 4. CHILLS
YES to 5. COUGH PRODUCTIVE OF PURULENT SPITUM
YES to 6. PERSISTENT COUGH (LONGER THAN 2 MONTHS)
NO to 7. PLEURITIC CHEST PAIN (WITH BREATHING)
NO to 8. PLEURITIC CHEST PAIN (WITH COUGHING)

Select the index corresponding to the question whose response you would like to change. *** Separate multiple indices by a blank. ***
For example, if you wanted to change questions 2,3,7 and 10, you would enter --> 2 3 7 10

Figure 8. History questions for Acute Bacterial Bronchitis.
The number left of each diagnosis is the probability that the patient has that disease or ailment. These values are determined within the HELP sectors and are a reflection of symptom-related disease occurrence as documented in current medical literature, "inhouse" statistical analysis and the experience of the medical expert who wrote the respective sector(s).

When the patient's attending physician signs onto the computer and calls up the history review program, these top five diagnoses will appear. In this case both pneumonia and mycoplasma pneumonia are displayed. This redundancy is built into the system. The computer is actually trying to determine what type of pneumonia the patient may have.

The patient's physician might wonder why the computer has selected acute bacterial bronchitis as a possible diagnosis. To review the history questions by diagnosis the user selects option #2. The physician then selects index #3 to indicate he or she would like to review the history questions which generated acute bacterial bronchitis. The computer retrieves all history questions searched for in that sector. Keeping these codes, it looks for matches in the patient's data file. Only those questions found in the patient's file which match the sector's questions will be displayed at the terminal (Fig. 8). The physician may know that the patient answered question #5 incorrectly, that the patient does not have purulent sputum and may change the response from "yes" to "no" by typing "5" on the keyboard. If more than one response is incorrect, the user may indicate this by entering the additional indices, separated by
blanks. In this case the physician decides no other changes are necessary. The computer makes the revision along with changes to the unselected indices (to indicate they were reviewed but not changed), and stores them in the patient file. The current time is also stored with these questions to indicate when the physician reviewed the history questions for this particular sector. HELP is then run on the newly revised patient file to generate a new set of diagnoses (Fig. 9). In this case response changes caused acute bacterial bronchitis to drop to fourth place with a lower probability of 0.03. Pneumonia also decreased in probability. Mycoplasma left the list whereas influenza was a new addition.

If the physician wants to review the patient's history by a medical specialty he or she has particular interest in, option #1 is selected on the beginning screen (Fig. 9). The list of specialties appears (Fig. 4) and the user enters #4 to indicate they are interested in reviewing history questions the patient has answered which are related to the cardiopulmonary area of medicine. The computer determines cardiopulmonary history questions are under field code 120 in the database hierarchy. It searches for all field code 120 history questions stored in the patient's file and displays them, fifteen at a time, to the physician (Fig. 10). The physician may change any or all of the responses if he or she wishes. In this hypothetical case no changes are made. Second and third screens are displayed and again the physician makes no changes (Fig. 11). The displayed questions are restored into the patient's file. They now have a new (current) time parameter and a response value which
***** CURRENT 5 MOST PROBABLE HELP DECISIONS *****

1.00 CHRONIC BRONCHITIS (HISTORY)
0.15 PNEUMONIA (HISTORY)
0.03 INFLUENZA (HISTORY)
0.03 ACUTE BACTERIAL BRONCHITIS (HISTORY)
0.02 REACTIVE AIRWAY DISEASE (ASTHMA) (HISTORY)

Select the type of response you would like to review:

1. Questions referring to specific medical systems.
2. Questions that generate a specific diagnosis.
3. List top 5 HELP decisions at your terminal.
4. Printout of the top 5 HELP decisions and history questions.  
   (Type 's' to STOP.)

Figure 9. Revised HELP diagnoses and option menu.
The patient responded in the following way to history questions:

1. PRODUCIVE COUGH
2. PRESENTLY SHORT OF BREATH
3. DYSPNEA ON EXERTION
4. MORNING INCREASE IN COUGH
5. RECURRING COUGH AND SPUTUM PRODUCTION
6. DAILY COUGH IN THE WINTER
7. SIMILAR COUGH A YEAR AGO
8. ONSET OF DYSPNEA OVER MINUTES
9. CHRONIC DYSPNEA
10. COUGH AWAKENS PATIENT AT NIGHT
11. RECENT COUGH
12. DYSPNEA
13. PERSISTENT COUGH (LONGER THAN 2 MONTHS)
14. HEMOPTYSIS
15. COUGH PRODUCTIVE OF BLOOD-STREAKED SPUTUM

*** MORE QUESTIONS REMAIN ***

Select the index corresponding to the question whose response you would like to change. *** Separate multiple indices by a blank. ***

For example, if you wanted to change questions 2, 3, 7 and 10, you would enter --> 2 3 7 10

Figure 10. History questions for cardiopulmonary category. Additional questions are presented in Figure 11.
N 16. ACUTE CHEST PAIN
N 17. CHEST PAIN, SUBSTERNAL
N 18. CURRENT CHEST PAIN
N 19. RESPIRATORY PROBLEMS SINCE AN EPISODE OF PNEUMONIA
N 20. FREQUENT RESPIRATORY INFECTIONS
N 21. COUGH EXACERBATION WHEN LYING ON ONE SIDE
N 22. RECURRENT PNEUMONIAS IN ONE LOCATION
N 23. HISTORY OF PNEUMONIA
N 24. POSITIVE TUBERCULOSIS SKIN TEST (PPD)
N 25. ORTHOPNEA
N 26. PAROXYSMAL NOCTERNAL DYSPNEA
N 27. COUGH PRODUCTIVE OF MORE THAN 1/4 CUP OF SPUTUM
N 28. RECENT CHEST PAIN
N 29. EXERTIONAL DYSPNEA FOR MONTHS TO YEARS
N 30. SUDDEN ONSET OF DYSPNEA

*** MORE QUESTIONS REMAIN ***

Select the index corresponding to the question whose response you
would like to change. *** Separate multiple indices by a blank. ***
For example, if you wanted to change questions 2, 3, 7 and 10, you
would enter --> 2 3 7 10

( ANOTHER SCREEN IS PRESENTED )

N 31. ONSET OF DYSPNEA IN RECENT DAYS OR WEEKS
N 32. USES OXYGEN AT HOME
N 33. HISTORY OF ASTHMA
N 34. PLEURITIC CHEST PAIN (WITH BREATHING)
N 35. PLEURITIC CHEST PAIN (WITH COUGHING)
N 36. COUGH PRODUCTIVE OF PURULENT SPUTUM

Select the index corresponding to the question whose response you
would like to change. *** Separate multiple indices by a blank. ***
For example, if you wanted to change questions 2, 3, 7 and 10, you
would enter --> 2 3 7 10

Figure 11. Additional questions relating to cardiopulmonary.
indicates the questions were reviewed but not changed. Because no changes were made, HELP processing is not needed and the beginning screen with the previous top five diagnoses will reappear (Fig. 9). Processing time is decreased considerably when no changes are made.

By selecting option #4 on the beginning screen (Fig. 9) the user can obtain a printout of the top 5 HELP decisions/diagnoses and related history questions. The report is sent to the nearest computer printer. This hard copy can be a valuable educational tool because it lists questions that correspond to the specific diagnoses. They tell the physician "why" a particular probability is associated with a certain diagnosis. A typical history report printout can be found in Appendix E. The physician may stop the review process and reenter the query program by typing "s" or "S."

At this point the system reenters the querying process. If any new questions have been generated from physician changes in the review/edit program, they will be presented to the patient when and if the patient signs back onto the computer. Hence, the changing of history question responses may open new lines of diagnostic reasoning.

This review method is used in conjunction with the query system for taking a computer-generated medical history at the patient's bedside. The review program is only available to attending physicians. They may access it at the bedside terminal. At present, two pulmonary care rooms have dedicated bedside terminals. A third terminal has been mounted on a mobile cart to facilitate history taking with other pulmonary patients around the hospital.
Like all new systems which require changes in medical practice, the greatest challenge to the review program was enticing physicians to use the system. This meant making them comfortable with the operation and instructing them how to take full advantage of its capabilities.

To familiarize the three pulmonary physicians participating in the study with the proper use and capabilities of the system, demonstrations were given. Afterwards a simple step-by-step instruction sheet was attached to each bedside terminal to remind them of the procedure. In addition, several followup inquiries were made to persuade physicians to use the terminal review system.

The reviewing scheme was installed clinically in February 1985. Allowing one month of debugging, the actual experiment began the first week of March. It ended six months later during first week of September.

The goal of the experiment was to determine if physicians would use a system of this type. The experiment was also to reveal if physicians preferred to examine patient responses to historical questions in a review of physiological systems approach or as explanations for the specific HELP diagnoses they invoked. Additional insight into physician acceptability of the computer-directed history
was also sought.

To monitor physician use and measure other experimental aspects, a data collection algorithm was added to the review program. Every time a physician accessed the review program, a statistics collection file was opened. The patient's hospital number was stored along with other variables necessary to record the way the process was used. These variables were incremented to reflect multiple use of the various review options. Storing patient numbers allowed the researcher to identify physicians who accessed the terminal review program.

Supplemental information was supplied through paper questionnaires attached to printed pulmonary history reports. These report/questionnaires were produced by utilizing the printed report option in the review process. A graduate student directed the report generation after each computer-directed pulmonary history was taken. These report/questionnaires were printed at the nearest nursing station and placed in the patients' chart. They were used only for research purposes and therefore were not part of the permanent patient record. It was anticipated that physicians would see these reports in the chart, respond to the questionnaire prompts, and return them to the Biophysics Department for evaluation. Questions polled physician attitudes on diagnostic validity and accuracy of patient responses to the computer-directed history questions. Suggestions to improve the document were also solicited. Later in the study, these reports were placed in the physicians' hospital mailboxes to insure they received them.

One of the many problems encountered during the project was
scheduling pulmonary patients of the three participating physicians into the two rooms with bedside terminals. Often patients of other physicians were admitted into these rooms. Problems in room scheduling and load management made the placement of desirable patients a "hit and miss" occurrence. Because of this, many possible study patients had their histories taken with the mobile terminal. Due to its nature, the mobile terminal was never available to physicians for reviewing a specific patient's history.

Another problem of major consequence was the discovery that the physicians were not using the terminal history review process. Despite continued efforts to reverse this trend, no actual utilization of the program occurred.

At the conclusion of the study period when it was apparent the physicians had not used the terminal review process, it was resolved to use an informal question/discussion interview to measure experimental parameters. Questions queried the physicians about attitudes concerning use of the system and what improvements would make the system more acceptable. Because most of the physicians' experience with the system was limited to reviewing the printed report, almost all of the questioning concerned the report. Nine specific questions were asked:

1. Is the information supplied by the computer directed pulmonary history report (filed in the patient's chart) helpful?
2. Is it accurate?
3. Does this printed report adequately document the patient history?
4. Do you need to ask patients history questions in addition to those covered by the computer?

5. What additions to the history report would make it more useful?

6. Would you prefer to review a patient's historical data by diagnosis or physiological system?

7. Have you tried the history review system available at the bedside terminal?

8. Would you prefer to edit a patient's history using a computer terminal or by marking a printed history report?

9. What improvements are necessary to provide a document that would be acceptable to you as a permanent part of your patient's medical record?
CHAPTER 3

RESULTS

In the six month data gathering period, forty-one patients participated in the computer-directed history taking study. Of these patients, twenty used a bedside terminal. The remaining twenty-one patients used the mobile terminal to respond to the computer-directed questions.

Because the physician did not actually use the terminal review system, no data were gathered by the statistics counting algorithm. However, twenty-one report/questionnaires were returned for evaluation. Eight of these were from patients in rooms with a dedicated terminal. The other thirteen reports came from patients whose history was taken with the mobile terminal. Evaluation of data on patients with a returned report revealed that it took from 4 to 32 minutes to answer 14 to 112 pulmonary questions. The average time required was 11.7 minutes. Average number of questions answered was 58. Calculations disclosed the average amount of time to answer one question was 12.9 seconds. The range in this category was 5 to 24 seconds per question.

Of the twenty-one returned reports, three had physician comments on questions leading to a diagnosis. One of these disputed the use of dyspnea as a symptom of chronic bronchitis. The physician argued that dyspnea was more often a finding associated with asthma. Two
reports had comments concerned with HELP diagnoses. One of these identified a HELP decision as the correct diagnosis. The other report had a comment citing a non-HELP diagnosis. From informal discussion with the participating physicians, it was determined that the fourteen reports returned without comments were reviewed and found adequate. This information could be interpreted to imply the physicians generally found the printed reports to be accurate measures of patient pulmonary histories.

In response to the informal question/answer discussion, two of the three physicians claimed that the printed report was helpful. All three participants believed the report was usually accurate, especially with alert patients. When questioned about the printed report's adequacy, all three responded that it covered only a portion of the necessary historical information. A complete history was still needed and additional questions were asked to achieve this goal. They also agreed the report would be more useful if additional, nonhistorical data were included. Suggested additions include: information on previous therapies and hospitalization, blood gas results, X-ray results, prescribed drugs, chief complaint, and a list of problems which led to the hospitalization. (The problem lists developed by the PROMIS System (4) might be useful guides.)

The physicians were unanimous in choosing a review of systems approach to examine historical data. This format closely resembles traditional methods of data organization. However, they did indicate an interest in combining the review of systems with the diagnostic "why" format.
During the study none of the participating physicians accessed the terminal review/edit system on their own accord. Further discussion into why they avoided the terminal disclosed time constraints as the primary explanation. A secondary cause was expected discomfort at consulting a computer in the presence of a patient. The physician contended that using the bedside terminal could cause patients to lose confidence in the medical system. Another participant commented that he would never use a computer terminal to review patient data because paper evaluations were always responsive and quicker.

Remarks concerning the physicians' preference to edit historical data by computer terminal or marking a printed history report substantiated these results. Two of the three participating physicians indicated they preferred a paper editing scheme but would welcome the terminal approach if a terminal was in their offices. The third physician revealed that the paper method would always be preferred.

In order to make the history report a permanent part of the patient record, the following suggestions were made:

1) List information in the order it would normally be analyzed.
2) Add the patient's chief complaint and problem list.
3) Add previous hospitalization and therapies.
4) Increase information concerning exposure to harmful chemicals, dusts, occupational hazards and other agents.
5) Improve the "naturalness" of data delivery.
6) Format the document more concisely.

Throughout the study most patients were interested in using the computer. Informal discussion with participating patients indicated
they were impressed with the way the computer narrowed questioning down. One patient, a retired nurse, said she could see the computer "thinking" of what would be the next set of questions.
CHAPTER 4
DISCUSSION AND CONCLUSION

Discussion

It should be apparent that the history taking system described in this paper resolves many of the problems encountered in previous designs. Despite the success of the history taking system, the review program was only accepted in a minor role. The successful portion was the option to print out the patient's pulmonary history. Yet while the review system was not used to its utmost capabilities, it did prove to be a very informative pilot project.

Pertinent findings include:

1) Physicians should be well versed in computer operation before being selected to participate in a study similar to the history review/editing project.

2) Physicians in this study are ready to accept the patient/computer team as a valid data collection option.

3) Alert patients interact well with computer terminals at the bedside.

4) Physicians prefer to review data by more traditional methods but are interested in HELP generated diagnoses and their evoking findings.

The most obvious failure of the system was the lack of use by participating physicians. The main reason for their disassociation
was shortage of time. If terminals could be provided in their offices, it is likely the review/edit program would be utilized. One way to provide terminals would be to temporarily move the bedside terminals into the physicians' offices. Pulmonary histories could still be taken at the patient bedside using the mobile terminal. In this scheme researchers and nurses would not have to worry about getting pulmonary patients of the three participating physicians into the two bedside terminal rooms. Their histories could be collected from any bed in the hospital with a telephone hook-up. With exposure to the computer terminals, physicians might conceive ways for a computer to help them in their practice. Their suggestions in this regard might be of benefit to future researchers.

The success of the review system on the clinical level was limited to acceptance of the printed history report. Yet the entire history taking and review system would be more efficient if the printout option was removed from the review subsystem and incorporated into the general history taking process. If the report is to be generated for each patient that completes a computer-directed pulmonary history, it should be done automatically. These reports would be sent to the nearest nursing station.

Considering the lack of comments on the printed history reports and interview responses, it appears the physicians who participated in this study accept the computer-directed history questions and corresponding patient responses as valid items of medical information. This lack of criticism also implies that patients are able to respond surprisingly well to computer-generated questions.
The fact that the physicians preferred to review pulmonary history data in a system format rather than a diagnostic approach symbolizes their comfort with past data formatting schemes. While they were interested in the diagnostic listings and their accompanying evoking questions, they did not feel the information was as useful as the systems approach. Perhaps in the future, as they become more familiar with the system, physicians will regard the HELP system as a credible diagnostician.

It should be noted that the physicians always collected a pulmonary history of their own. These manually collected histories removed any incentive (other than curiosity or research) to review the computer-directed histories. In this regard, the experiment was lacking. Physicians should have been allowed to take a manual history only in supplementing information collected by the computer. The physicians simply did not have time to review both histories.

Presently a history taking system which encompasses more of medicine is needed. This project is underway. At LDS Hospital researchers and medical experts are already designing HELP sectors to "ASK" questions which will capture more historical information. As a complete history taking system evolves, it is hoped that physicians will become more comfortable with the terminal review system. It is only after they feel secure editing historical data on an on-line basis that a complete computerized history will be accepted at the clinical level. If used, the review/edit program could be an effective method for physicians to control a computer-collected history.
Conclusion

In summary, physicians do not appear ready to review data at a patient's bedside. However, they are eager to begin using a computer to access patient information if it does not interfere with their normal clinical duties. Physicians also seem willing to accept the patient/computer team as a viable information gathering tool.

Additionally, it should be noted that although the history review system was never directly used by physicians, it did prove to be a successful pilot project. Future projects of this type should benefit from information collected concerning patient capabilities with a computer terminal, physician attitudes towards computer use at the bedside, physician's preference for reviewing patient information, and the difficulties in implementing such a system.
APPENDIX A

TWO APPROACHES TO COMPUTER-ASSISTED MEDICAL DECISION MAKING

There are two main approaches to computer-assisted medical decision making. The first is mathematical and uses calculated probabilities to determine the most likely decision for a patient's care. The second approach uses a rule-oriented knowledge base to make decisions (23).

The most common mathematical model involves estimating how often a symptom or sign occurs with a diagnosis. In the HELP system a program termed STRATO allows researchers to gather data on patients who have specific symptoms and diseases. This information is stored in the extensive LDS Hospital computer files. These data can then be used in HELP sector probability statements. Here the HELP processor can integrate the values into Bayes' formula to determine the probability that a specific patient has the disease being evaluated.

The Bayes equation works best when the symptoms are not linked. In actuality, many symptoms for a particular disease may be related. Another problem occurs because mathematical models at best place the patient in a statistical population. Many physicians find it hard to understand the statistical probabilities (23).

The knowledge-based approach uses rules written by medical experts to make step-wise decisions in a manner that closely resembles
physician reasoning. Together the set of rules comprise the knowledge base, against which all decisions are made. The data driven hypothesis testing and ASK strategies in HELP qualify it as a knowledge base system.

A knowledge base cannot stand alone. Computers need some type of quantifying measure to make a judgement. A heuristic approach such as the one used by INTERNIST is one way to quantify the data. Another approach combines probabilities with a knowledge base. This is the technique chosen by researchers developing the HELP system.
APPENDIX B

REPRESENTATIVE HELP SECTOR

SECTOR 14 == ACUTE BACTERIAL BRONCHITIS (HISTORY)

A ARITH: 0.008
B SEARCH: (A) [FC] CONSTITUTIONAL, [N] HAVE YOU HAD A FEVER WITH THIS ILLNESS?, FROM: 0, TO: NOW, IF EX: A, USE VAL: A

C SEARCH: ^ (A) [FC] CARDIOPULMONARY, [N] HAVE YOU HAD A COUGH WITH THIS ILLNESS?, FROM: 0, TO: NOW, IF EX: VAL SUB ITEM AG 5, USE VAL: A

D SEARCH: # (A) [FC] CARDIOPULMONARY, [N] HAVE YOU HAD RECENT CHEST PAIN?, [ADV] IS YOUR CHEST PAIN INCREASED BY BREATHING DEEPLY?, (B) [ADV] IS YOUR CHEST PAIN INCREASED BY COUGHING?, MOD: MAX, FROM: 0, TO: NOW IF EX: A OR B, USE VAL: MAX(A, B)

E SEARCH: (A) [FC] CARDIOPULMONARY, [N] HAVE YOU BEEN SHORT OF BREATH WITH THIS ILLNESS?, FROM: 0, TO: NOW IF EX: A, USE VAL: A

F SEARCH: (A) [FC] CONSTITUTIONAL, [N] HAVE YOU HAD CHILLS WITH THIS ILLNESS?, FROM: 0, TO: NOW, IF EX: A, USE VAL: A


H SEARCH: # (A) [FC] CARDIOPULMONARY, [N] HAVE YOU HAD A COUGH WITH THIS ILLNESS?, [ADV] HAVE YOU COUGHED DAILY FOR MORE THAN 2 MONTHS?, FROM: 0, TO: NOW, IF EX: A, USE VAL: A

I PROB: A, IF EX: B OR F, USE VAL: MAX(B, F), MIN: (1, 5), TRUE: (0.5, 0.5), FALSE: (0.7, 0.3)

J PROB: I, IF EX: C AND VAL ITEM G LT 5, USE VAL: C, MIN: (1, 5), TRUE: (0.1, 0.9), FALSE: (0.8, 0.2)

K PROB: J, IF EX: D, USE VAL: D, MIN: (1, 5), TRUE: (0.95, 0.05), FALSE: (0.7, 0.3)

L PROB: K, IF EX: E, USE VAL: E, MIN: (1, 5), TRUE: (0.56, 0.44), FALSE: (0.7, 0.3)

M PROB: L, IF EX: G, USE VAL: G, MIN: (1, 5), TRUE: (0.35, 0.65), FALSE: (0.95, 0.05)

N PROB: M, IF EX: H, USE VAL: H, MIN: (1, 5), TRUE: (0.5, 0.5), FALSE: (0.2, 0.8)

O ARITH: IF N LT A THEN GOTO FE

P EXIST: ASK((PATIENT QUESTIONS)B, D, E, F, G, H)
APPENDIX D

PULMONARY HISTORY TEXT COMPARISON

dc fo noun adj adv History questions as they are viewed by a PATIENT
7 100 0 0 0 CONSTITUTIONAL
7 100 2 0 0 HAVE YOU HAD A FEVER WITH THIS ILLNESS?
7 100 10 0 0 HAVE YOU HAD CHILLS WITH THIS ILLNESS?

7 120 0 0 0 CARDIOPULMONARY
7 120 1 0 0 HAVE YOU HAD RECENT CHEST PAIN?
7 120 10 0 0 HAVE YOU HAD A COUGH WITH THIS ILLNESS?
7 120 10 22 0 DOES YOUR COUGH BRING UP ANYTHING?
7 120 10 22 4 IS THE SPUTUM YELLOW, GREEN OR BROWN?
7 120 10 22 6 IS YOUR SPUTUM WHITE OR CLEAR?

7 150 0 0 0 MEDICATIONS
7 150 2 0 0 HAVE YOU BEEN TAKING MEDICATIONS AT HOME?
7 150 2 12 0 ARE YOU TAKING BIRTH CONTROL PILLS?
7 150 2 14 0 HAVE YOU BEEN TAKING AN ANTIBIOTIC?
7 150 2 14 2 ARE YOU TAKING PENICILLIN?
7 150 2 14 8 ARE YOU TAKING STREPTOMYCIN?

dc fo noun adj adv Analogous messages available for PHYSICIAN review
57 100 0 0 0 CONSTITUTIONAL
57 100 2 0 0 FEVER
57 100 10 0 0 CHILLS

57 120 0 0 0 CARDIOPULMONARY
57 120 1 0 0 RECENT CHEST PAIN
57 120 10 0 0 RECENT COUGH
57 120 10 22 0 PRODUCTIVE COUGH
57 120 10 22 4 COUGH PRODUCTIVE OF PURULENT SPUTUM
57 120 10 22 6 COUGH PRODUCTIVE OF CLEAR SPUTUM

57 150 0 0 0 MEDICATIONS
57 150 2 0 0 MEDICATION
57 150 2 12 0 BIRTH CONTROL PILLS
57 150 2 14 0 ANTIBIOTIC
57 150 2 14 2 ANTIBIOTIC, TAKING PENICILLIN
57 150 2 14 4 ANTIBIOTIC, TAKING STREPTOMYCIN
APPENDIX E

PULMONARY HISTORY REPORT FORM

TEST, CHARLENE TWO  AGE: 56  ADMITTED: 01/24/1985.11:22
PATNUM: 2386  SEX: F  ROOM: W527

****** CURRENT 5 MOST PROBABLE HELP DECISIONS ******
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History suggests the following differential diagnosis:
0.86 PNEUMONIA (HISTORY)
--- because the patient complained of:
  FEVER
  CHILLS
  RECENT COUGH
  DYSPNEA
  COUGH PRODUCTIVE OF PURULENT SPUTUM

History suggests the following differential diagnosis:
0.47 ACUTE BACTERIAL BRONCHITIS (HISTORY)
--- because the patient complained of:
  FEVER
  RECENT COUGH
  DYSPNEA
  CHILLS
  COUGH PRODUCTIVE OF PURULENT SPUTUM

History suggests the following differential diagnosis:
0.33 ASPIRATION PNEUMONIA (HISTORY)
--- because the patient complained of:
  FREQUENT HEARTBURN

History suggests the following differential diagnosis:
0.02 EMPHYSEMA (HISTORY)
--- because the patient complained of:
  DYSPNEA
  EXERTIONAL DYSPNEA FOR MONTHS TO YEARS
  CHRONIC DYSPNEA

History suggests the following differential diagnosis:
0.01 REACTIVE AIRWAY DISEASE (ASTHMA) (HISTORY)
--- because the patient complained of:
  DYSPNEA
*** Note that a positive complaint could actually lower the diagnostic probability of a decision.

The patient denied:

- Pleuritic chest pain (with breathing)
- Pleuritic chest pain (with coughing)
- Dysphagia
- Acid/food regurgitates up into pharynx
- Acid/food regurgitates, chokes on fluid regurgitant
- Recent heavy ethanol intake
- Smoked for more than 10 years
- Sudden onset of dyspnea
- Onset of dyspnea over minutes
- Onset of dyspnea in recent days or weeks
- Long term weight loss
- Current asthma attack
- History of asthma
- Recent wheezing
- Previous asthma treated with intravenous meds
- Previous asthma treated with steroids
REFERENCES


