The automated medical history

by WILLIAM WEKSEL
Cytek Information Systems Corporation
New York, New York

and
PAUL N. SHOLTZ
IBM Corporation
Rochester, Minnesota

and
JOHN G. MAYNE
Mayo Clinic
Rochester, Minnesota

INTRODUCTION
It has often been suggested that computer technology could help solve problems in medicine. The Automated Medical History (AMH) system is designed to help the physician collect data from the patient. The system's objective is to lessen physician involvement in routine activities, thereby increasing his availability to provide patient care. The AMH should help alleviate the chronic shortage of medical personnel even as it extends the physician's capabilities to collect patient information.

Collecting data from patients involves many related activities that can be roughly categorized as history taking, physical examination, and laboratory tests. It is difficult to determine precisely the relative importance of these activities. However, physicians generally believe that the patient's medical history has basic importance in interpreting medical findings. For this reason, the medical history is a logical starting point for developing techniques to aid the physician in his data collection activities.

We propose that information technology be used as an adjunct to the traditional physician-patient relationship, specifically for collecting medical history data. The feasibility of using computer technology has been demonstrated and discussed in another paper. This paper describes the AMH system and briefly reviews the system's data collection capabilities. It also discusses the possibility of using the AMH to evaluate the medical data collected.

The Automated Medical History (AMH)
The AMH is a medical questionnaire that is presented to a patient on a display terminal. An IBM 1050 Data Communication System is used to enter patient identification information and to print the summary of each patient's responses. This standardized, legible, condensed summary is sent to the physician before the physician-patient interview.

The display terminal projects photographic images that are stored on 16 mm color film (Figure 1). This terminal is a prototype of the recently announced IBM 2760 Optical Image Unit. Images can be selected in any order by the computer. Patient responses are entered on the display terminal with an electronic light pen. An array of response areas is arranged in a 10 by 12 matrix, making possible 120 unique responses on each frame.

Colors emphasize the three functional areas of
Color photographs and pictorial techniques are also used to supplement written explanations of medical terminology. For example, if a patient does not understand a question about “skin cancer” or some other skin condition, a picture of the condition can be shown (Figure 3). Pictorial techniques also allow the patient more freedom of expression. For example, this illustration permits him to specify the location of abdominal pain (Figure 4).

Computer-administered questioning permits the effective use of question branching. This means a questionnaire can be tailored to the individual patient, so that factors such as sex, age, education, and ability to understand questions can be accounted for. Moreover, the patient answers only those questions which pertain to his own medical problems.

Question branching is based on responses given by the patient. Specific uses of branching in the AMH will be considered later in this paper.

Computer administration permits control over each frame, which are the question, the response alternatives, and the instructions (Figure 2).
the patient while he is answering the questions. That is, the patient must answer all questions because the questioning process will not proceed until an answer is given. The computer can also monitor patient performance by recording such things as undue delays and excessive erasures.

AMH system description

The graphic display terminal and the IBM 1050 Data Communication System are controlled by an IBM 7040 Data Processing System. To permit efficient use of the computer, the operating system was modified to permit concurrent operation of terminal service programs and background programs. Experience indicates only 1% to 2% of available computer time is required for terminal activities.

A special purpose language was developed to permit computer control of the graphic display terminal activity at each step of the questionnaire. This language was specifically designed to simplify the display of particular film frames, the manipulation of light pen coordinates, and the control of branching operations. Also included were extensive text composition facilities, for use in construction of the summary statement.

The experimental graphic display terminal seems ideally suited to this particular application. It has been operated successfully by completely untrained users (patients) who had very brief instructions. There are two reasons for the suitability of this terminal: first, very high quality colored images are obtained by photographic projection, and second, a very simple and direct method of response is made possible by the use of the light pen.

The questionnaire

The questionnaire consists of broad, inclusive, screening questions organized according to conventional body systems. These questions attempt to detect the presence of actual or potential disease states. The questions are all of the fixed choice type. Response alternatives vary from a simple "yes," "no" to multiple choice check lists describ-
ing symptoms and conditions. The format usually is dictated by the objectives of a specific question (for example, see Figures 5, 6, 7). The number of questions asked varies from patient to patient because of question branching. It ranges from 226 to 302 questions for females, and from 212 to 283 for males.

Currently, there are four uses for branching in the AMH:

1) To ask the patient questions that pertain only to his specific problems.

2) To explain questions and medical terminology that the patient does not understand. For example, if a patient does not understand a question about “yellow jaundice” (Figure 8), he is shown this explanation (Figure 9). If he indicates that he understands, he is shown the original question again. If not, he goes on to further questions. The fact that he did not understand the “yellow jaundice” question is recorded in the summary.

3) To give the patient greater latitude when describing his medical problem. For example, if a patient indicates he has abdominal discomfort (Figure 10), question branching provides various descriptions of such discomfort (Figure 11). Although many of these terms are redundant and have no differential diagnostic value, the patient can give his answer in words familiar and meaningful to him.

4) To evaluate the significance of a positive response, using branching questions to distinguish between common occurrences and significant medical symptoms. For example, if a patient complains of a headache, he is questioned on aspects of the headache such as severity, frequency, duration, and his concern about it. These questions permit assessment of whether or not the headache is a significant symptom that requires medical follow-up or whether it is an unimportant occurrence that requires no further investigation. This is an important use of question branching that
Have you ever had yellow jaundice?

- Yes
- No
- Don't understand

- Go back

Figure 8—Yellow jaundice question

Evaluation of the AMH

One hundred fifty-nine Mayo Clinic patients were randomly selected for AMH administration. The highlights of this experiment were:

1) Patient reaction was extremely favorable. Of the 159 patients sampled, 154 participated; only two reacted unfavourably.
2) All patients were able to answer the questionnaire and operate the terminal. Mean patient age was 50.1 years (95% confidence limits were $48.5 < \mu < 51.7$) and mean education level was 11.8 years (95%: $11.4 < \mu < 12.2$). This suggests that a high education level is not necessary for successful participation.
3) Physician reaction was favorable. The tone and extent of the criticisms received indicate physician acceptance of the AMH in its role as collector of medical histories.
4) Mean questionnaire completion time for patients (95%: $62.2 < \mu < 69.2$) was 65.7 minutes.
5) The AMH obtained 95% of the symptom information recorded by the physician in the traditional patient record. This study compared patient symptoms obtained by the AMH to those recorded by the examining physician in the patient’s Mayo Clinic Medical Record.
6) Comparisons between the traditional patient record and the AMH summary with respect to “past surgery” and “past illness” information suggest that, given the total set of patient responses, the AMH data collection performance was significantly better than that of the physician (Table I).
Table I

Two-Way Comparison: AMH Data vs Physician-Recorded Data

<table>
<thead>
<tr>
<th>Item</th>
<th>Proportion of physician-recorded data also obtained by AMH (%)</th>
<th>Proportion of AMH-obtained data also physician-recorded (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Past surgery*</td>
<td>86</td>
<td>62</td>
</tr>
<tr>
<td>Past illness*</td>
<td>59</td>
<td>39</td>
</tr>
<tr>
<td>Past family illness and cause of death</td>
<td>57</td>
<td>62</td>
</tr>
</tbody>
</table>

*Difference statistically significant, P > 0.05

These results indicate that reliable medical history gathering techniques can be developed to aid the physician.

Use of the AMH for the evaluation of medical symptoms

We have already indicated that branching can be used to evaluate the significance of positive symptoms. Such an evaluation has two aspects. Given a positive response to a question, should it be followed up? If it is followed up, what is the best way—more questions, laboratory tests, or physical exam? We will consider the first aspect of the problem.

We attempt to obtain additional information (on a positive symptom) that will help us decide whether or not the symptom is significant enough at the system review level to require more questioning. For example, if a patient indicates that he has headaches, we need information regarding headache severity, frequency, and duration, as well as the degree of the patient's concern about his headaches. Some combination of these items should form the basis for deciding whether or not the patient's positive response to the headache question requires follow-up.

We need to find which patient responses, singly or in combination, are the most important determinants of whether or not a physician follows up on his patient's complaint. This knowledge would allow us to assign relative weights to various pa-
of these was the “likelihood ratio” which is represented by the relative frequency with which a symptom or set of symptoms occurred in the follow-up groups ($P_f$) as compared to the relative frequency with which the same symptom or combination of symptoms occurred in the non-follow-up groups ($P_{nf}$). That is, the ratio was

$$\theta = \frac{P_f}{P_{nf}}$$

The assumptions underlying the use of $\theta$ and its use for item analysis has been dealt with by Neyman and Collen and will not be discussed here. These authors indicate that the resulting $\theta$ can be used as the basis for establishing sets of values for which a diagnosis will be positive and sets of values for which a diagnosis will be negative. We have sought to examine only the discriminative value of the items in the question branches.

Table II repeats these values for the branch of questions used to evaluate a positive headache response. In this table, we show the relative frequencies of occurrence of different categories for headache duration, frequency, severity, incidence of relief with simple medications, and the patient’s concern about his headache. Clearly, duration—

<table>
<thead>
<tr>
<th>Table II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discriminative Value of Features Which Describe Headaches ($n = 77$)</td>
</tr>
<tr>
<td>Feature</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>Duration</td>
</tr>
<tr>
<td>&lt; 1 year</td>
</tr>
<tr>
<td>Between 1-5 yr</td>
</tr>
<tr>
<td>More than 5 yr</td>
</tr>
<tr>
<td>Frequency</td>
</tr>
<tr>
<td>Increasing</td>
</tr>
<tr>
<td>Same</td>
</tr>
<tr>
<td>Decreasing</td>
</tr>
<tr>
<td>Perceived Severity</td>
</tr>
<tr>
<td>Increasing</td>
</tr>
<tr>
<td>Same</td>
</tr>
<tr>
<td>Decreasing</td>
</tr>
<tr>
<td>Relief with simple medicine</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Patient concern</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
</tr>
</tbody>
</table>

End of session.

Figure 12—Summary statement

tient responses when evaluating positive symptoms. This knowledge would also give us a statistical basis for determining the discriminative power of each individual question. Using this statistical basis, items with low discriminative power could be discarded.

In our investigation, patients with positive responses to questions regarding the incidence of "headache" were grouped. Then, on the basis of the information extracted from the patient record, this group of patients was subdivided into those who had a follow-up exam on headaches (hereafter referred to as the follow-up group) and those who did not have a follow-up exam on headaches (hereafter referred to as the non-follow-up group). "Follow-ups," then, had further investigation by the physician regarding their headache problem. In some cases, this was in the form of a head x-ray; in other instances it was a consultation with a neurologist regarding the headache problem, or a final diagnosis was made which suggested that the headache problem had been followed up.

Two statistical techniques were used to investigate the relative importance of the items used to evaluate the routine headache response. The first
that is, whether a headache has lasted less than a year, between 1 and 5 years, or more than 5 years—seems to have no bearing on whether or not the physician follows up on a patient. There is no significant difference between the groups in this case. Whether or not the groups are significantly different is the basis for deciding whether or not the ω's are of any value.

The other categories in the headache branch are more important, as significant differences were found between the patient groups. Notice that the ratio of the ω's to one another is high from the positive to the negative response. Someone who has any one (or all) of the following: headaches that are increasing in frequency, headaches that are increasing in severity, or concern for his headaches without being able to obtain relief with simple medications, is likely to receive a follow-up examination.

How do these features relate to follow-up when they are combined? And, in combination, which of these items is the most important? To determine this, a multiple correlation analysis was done in which the criterion variable was membership in the follow-up group and the predictors were the items listed in Table II. The results of this analysis are listed in Table III. The multiple correlation is .54, which is statistically significant. The third column of this table, which lists the regression coefficients, shows the relative importance of each of the independent variables in influencing the criterion or dependent variable. We can see that the most important variable is the patient’s concern, which has the largest regression coefficient. Note that this variable had the largest ratio between ω’s, as seen in Table II.

Using this information, it is possible to assign relative weights to responses of future patients. The combination of these relative weights would be the decision procedure used to determine whether or not physician follow-up is required.

A similar analysis was performed with respect to “neck pain.” In this analysis, only two items were in the branch: association of the pain with nervousness, and past occurrences of neck pain. The theory was that neck pain consistently associated with nervousness was not significant. Similarly, if the patient had previous neck pain, it was not as important as if the neck pain was a new phenomenon. Table IV bears this out. Patients with neck pain not consistently associated with nervousness were found in the follow-up group more often than in the non-follow-up group. The item regarding past occurrences was less important.

These findings are consistent with the multiple correlation analysis presented in Table V. The association of neck pain with nervousness seems to be the most important variable.

It should be noted in both the headache and neck pain cases that although the multiple correlations are significant, they are low enough in magnitude to indicate that there are many other reasons which relate to being assigned to the follow-up group. Some of these reasons may be neurological complaints given in response to other questions.
Table V


<table>
<thead>
<tr>
<th>Predictor Variables</th>
<th>Zero Correlation (with criterion)</th>
<th>Regression Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Association w/nervousness</td>
<td>-0.47</td>
<td>-0.28</td>
</tr>
<tr>
<td>Past occurrences</td>
<td>-0.17</td>
<td>-0.15</td>
</tr>
</tbody>
</table>

Multiple R = .50
F value = 8.6, F > F.05

To establish these relationships with other questions is a much larger problem than the one we have considered in this paper. At present, however, it seems apparent that the techniques we have discussed will enable us to find criteria for deciding whether or not particular positive instances require further investigation or whether they can be considered unimportant occurrences.

SUMMARY

The Automated Medical History is a system to collect medical history information from patients by using a computer-controlled display terminal. Computer administration permits effective use of branching techniques, thus making possible an individualized questionnaire for each patient. Patient responses are condensed into a concise summary statement for the examining physician.

The system was tested with 159 patients. Patients and physicians reacted favorably to the system. The AMH obtained approximately 95% of the information recorded by the physician in the patient’s medical record.

The possibility of using the AMH to evaluate the significance of the data collected was also explored.

REFERENCES

1 J G MAYNE W WEKSEL P N SHOLTZ
   Toward automating the medical history*

2 J NEYMAN
   First course in probability and statistics
   Henry Holt New York 1950 Chapter V

3 M P COLLEN
   Machine diagnosis from a multiphasic screening program
   Proceedings of the Fifth IBM Medical Symposium October 7–11 1963 Endicott NY

*Additional references (12) are cited in this paper.