A Computer-based Teaching Program in Hemostasis

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We have developed a natural language computer program that teaches a clinical approach to disorders of blood coagulation. The purpose of the program was fourfold: to teach a specific set of facts that we considered important to an understanding of hemostasis, to simulate an actual clinical setting in which the student determines the order and content of his patient evaluation; to be adaptive to a student's responses; and to provide for ready retrieval of student responses. The program is now constructed in two sections. The first section comprises general purpose instructions to the computer that analyze and store input and display the next portion of the lesson according to rules that are independent of the text. The second element consists of specific teaching context. This format allows ready adaptation of the program to teaching other areas of hematology. Experience with the system demonstrates that new subject matter can be easily programmed and revised, that second-year medical students like the approach, and that the subject matter can be effectively taught.

We have developed a computer program that teaches a clinical approach to disorders of blood coagulation. The program can be made available as a local telephone call from Boston, Chicago, Pittsburgh, Houston, Oklahoma City, New York, Phoenix, and Washington, D.C. It, therefore, seems appropriate to describe its evolution, its content, and conclusions derived from its use as part of the Harvard Medical School Course in Hematology. A second purpose of this report is to describe the flexible yet relatively simple text-manipulating technique that made it possible to write the program easily, for this technique is readily adaptable to other topics in hematology and to computer-aided instruction in other areas of medicine. The teaching program evolved from a series of problem-solving cases in hemostasis developed by one of us as part of the curriculum in hematology for second-year students at Harvard Medical School. Because of the positive response of students to self-teaching exercises, and because the subject matter, hemostasis, contained a specialized and relatively predictable medical vocabu-
lary, we elected to construct an adaptive, tutorial computer program that could communicate with the student in ordinary English prose.

The goals of the program were fourfold. The first was to teach ten specific facts that we considered important to an understanding of blood clotting so that a pool of students would recall them several days later with an accuracy of at least 75%. The second goal was to present cases that would guide the student through the principles of history-taking and physical examination pertinent to the evaluation of a bleeding disorder, instruct him in evaluation of laboratory tests of hemostatic function, and consider with him differential diagnosis and treatment. Our aim was simulation of an actual patient encounter in which the student is free to select the order of his evaluation and to choose whatever laboratory tests he deems appropriate to the clinical situation. The third goal was to create a program that would be adaptive to the student’s response in that the computer would recognize and comment constructively on answers that were correct, incorrect, or partially correct. For example, it was our intent that the program would inform the student if he had selected too many tests, too few tests, or an inappropriate one and that it would respond with positive reinforcement when the student’s response was appropriate. The program allows the student to request additional instructional material at any time and to proceed at his own pace. The exact content of a teaching session depends on an on-going evaluation of student performance. The dialogue is determined by the student’s choice of answers, by his expression of interest in certain areas, and by his pattern of errors. Students who answer questions correctly pass quickly through the basic questions and are offered additional, advanced material. By contrast, students who make frequent mistakes are drilled on basic concepts and offered remedial information. Our final aim was to provide for ready retrieval of the students’ responses so that instructors can evaluate performance of the program and identify areas in which students’ knowledge is weak, information that allows correction of misconceptions in subsequent classroom sessions. Work of other investigators suggested that these goals would be attainable.1-5

MATERIALS AND METHODS

Description of the Hemostasis Teaching Program

In an effort to achieve these aims two teaching cases were constructed, both of which present patients with acquired disorders of hemostasis. The first case dwells in detail on fundamentals of hemostasis, whereas the second case is more advanced. The teaching strategy of both cases is the same. After a brief description of the patient, the student is asked to proceed with his evaluation in natural language. The program guides him through the performance of history and physical examination, requesting specific details of each.

Representative dialogue between student and computer is presented in Fig. 1. In this example, the student responds to a brief description of the patient with a request for laboratory data. The program guides him to a discussion of the patient’s history where an attempt is made to be as helpful as possible in responding to the rich variety of questions that the student could ask. The program keeps a continuous record of the subject matter covered, and it uses this information as a basis for guiding subsequent discussion. It
P: AT 11:00 PM ON CHRISTMAS DAY A 23 YEAR OLD AGITATED, WEEPING, NURSE IS BROUGHT TO THE EMERGENCY WARD WHERE YOU ARE ON DUTY. SHE IS BLEEDING FROM HER NOSE AND GUMS AND HAS MULTIPLE ECCHYMOSSES. HOW WOULD YOU PROCEED?

S: I WOULD GET A CBC.

P: NO. IT IS IMPORTANT TO PLACE YOUR PATIENT IN PERSPECTIVE. WHAT MORE GENERAL PROCEDURES MIGHT HELP YOU IN THIS RESPECT?

S: A DETAILED HISTORY IS THE MOST IMPORTANT THING.

P: GOOD. AND AFTER THE HISTORY A CAREFUL PHYSICAL EXAMINATION SHOULD BE DONE. SPECIFICALLY, WHAT TYPE OF INFORMATION WOULD YOU WANT TO OBTAIN IN TAKING THIS GIRL'S HISTORY?

S: HAS SHE HAD ANY BLEEDING IN THE PAST?

P: THE NURSE JUST KEPT SHAKING HER HEAD. HER FRIEND WAS UNAWARE OF ANY PREVIOUS BLEEDING DISORDER OF ANY KIND.

S: IS SHE TAKING ANY MEDICATIONS?

P: IT IS VERY ASTUTE TO ASK ABOUT DRUGS, DOCTOR JONES!

S: IS SHE KNOWN TO HAVE ANY ILLNESSES?

P: SHE HAS PREVIOUSLY BEEN IN EXCELLENT HEALTH WITH NO RECOGNIZED DISEASE. YOU ARE BEING VERY THOROUGH. GO ON.

S: IS THERE A FAMILY HISTORY OF SIMILAR DISORDERS?

P: THE NURSE DENIED THAT ANY OTHER MEMBER OF HER FAMILY HAD EVER HAD A SIMILAR PROBLEM.

S: HAS SHE HAD SURGERY?

P: SHE DID NOT BLEED EXCESSIVELY FOLLOWING AN APPENDECTOMY TWO YEARS AGO AND HAS HAD NO RECENT TRAUMA. ANOTHER QUESTION?

S: DENTAL EXTRACTIONS? OR IS THAT NEGATIVE TOO?

P: VERY GOOD. THIS CAN GIVE A VALUABLE LEAD. SHE NEVER HAD ANY TEETH EXTRACTED, HOWEVER.

S: TELL ME ABOUT HER DIET.

P: A LONG SHOT, BUT WORTH INVESTIGATING, DOCTOR JONES. AFTER ALCOHOLICS AND ELDERLY RECLUSES I SUPPOSE YOUNG WOMEN ARE MOST LIKELY TO HAVE PECULIAR EATING HABITS. BOTH VITAMIN AND PROTEIN DEFICIENCIES CAN LEAD TO BLEEDING DISORDERS WHEN EXTREME. CONTINUE.

S: EMOTIONAL INSTABILITY?

P: SORRY, I DON'T UNDERSTAND "EMOTIONAL INSTABILITY?" TRY AGAIN.

S: ANY PSYCHIATRIC PROBLEMS?

P: EXCELLENT. MENTAL STATUS IS AN IMPORTANT PART OF EVERY PATIENT'S EVALUATION. THIS GIRL IS CRYING AND OBVIOUSLY UPSET AT PRESENT. HER FRIEND VOLUNTEERS THAT SHE HAS BEEN VERY MOODY LATELY AND THAT SHE DID NOT WANT TO LEAVE HER ROOM TONIGHT. CONTINUE.

S: INCIDENTALLY, WHEN DID THIS BLEEDING START?

P: THE NURSE'S FRIEND STATES THAT THERE WAS NO EVIDENCE OF BLEEDING THAT MORNING. WHAT ELSE WOULD YOU LIKE TO KNOW?

Fig. 1. Representative typescript of portion of a lesson. Information typed by program is labeled “P;” student's responses are labeled “S.”

should be emphasized that the dialogue shown in this figure is but a small fraction of that comprising the lesson; after completing the discussion of history the program proceeds to physical examination, laboratory tests, differential diagnosis, and treatment of the clotting disorder. To begin the discussion of laboratory tests, the student is asked, “What screening tests would you perform?” The answer recognized as correct is: examination of the peripheral smear, prothrombin time, activated partial thromboplastin test, and, if there are adequate platelets on the smear, a bleeding time. If the student indicates too many or too few tests then each omission or superfluous item is commented on, and a revised
COMPUTER-BASED TEACHING PROGRAM

Fig. 2. Partial diagram of teaching strategy. Not shown are additional pathways, such as those that permit student to say "I don't know" and that present additional remedial material when student repeats mistakes.

list is requested. A diagram outlining the logical flow for this section of the program is shown in Fig. 2. After discussing differential diagnosis and therapy the program concludes with references for future reading.

It should be emphasized that throughout the session the program is sensitive to the student's feelings. It continually reinforces him with pleasantries, it stresses positive aspects of a response that is partially correct, and it patiently encourages repeated attempts when he is having difficulty.

Our initial program was written for an IBM 360, Model 60 computer in COURSEWRITER, a computer language designed specifically for teaching. The student communicated with the computer over ordinary telephone lines with the aid of a terminal that resembled an electric typewriter. When the program was started, it requested identifying data and then typed the initial portion of the case presentation. The student would then respond on the keyboard, and the computer would analyze and reply. Since the computer was being used simultaneously for other tasks given higher priority, its response
was often preceded by distracting delay. Furthermore, in the COURSEWRITER language, instructions to the computer are integrated with the content of the lesson, and for this reason modification of a lesson requires modification of the code in the program, which is often a considerable task.

Like previous computer teaching programs that permit the student to communicate by typing ordinary English text, our COURSEWRITER program required a considerable fraction of a large computer to process the many possible student inputs. Various groups have cited costs/student hr in such systems that are competitive with conventional teaching in medical schools.6,7 Such favorable estimates depend on economy of scale, whereas, in fact, heavy usage of many terminals is probably unrealistic during the introductory phase of a new technique.

The present program is written in an advanced version of MUMPS,8 and it has been specifically designed to facilitate change. It runs on a PDP-15 computer (MUMPS language, 24 terminal system) and entails a computer hardware cost/terminal device of about one-fifth that of a typical larger computer (IBM 360/30 computer, COURSEWRITER language, 20 terminal system). Students use Datapoint model 3000 cathode ray tube terminals that can silently display up to 24 lines of 72 characters at 300 words/min, twice as fast as the IBM terminals. Each session is stored in the computer and can be regenerated on a teletypewriter.

The new program has two distinct structural elements. The first element comprises general purpose instructions to the computer that analyze and store input and that display the next section of the lesson according to rules that are independent of the specific text. This element or “driver” is used with all teaching programs in this system. The second element consists of specific teaching content and formulas by which the physician-author monitors the student's performance and selects appropriate text.

Construction of the Computer Lesson

To construct a computer lesson, the physician-author organizes the subject matter into distinct presentations followed by the comments that he wishes to make to the various responses that the student may type. He also indicates how each response will modify the presentation and evaluation of subsequent questions and answers. A lesson loading program permits a person unfamiliar with the program to enter most of this information into the computer where it is stored in the required format. In some instances, formulas for monitoring the student's performance must be entered with the help of a programmer. When the teaching program is used by a student, responses are recognized according to character patterns and key words. By employing a list of character patterns and key words, the program can recognize a large number of potential responses, including abbreviations and misspellings, while the list remains short enough for rapid screening during execution. For example, the key words “FAM & BLEED” are one anticipated answer to the question, “What type of information would you want to obtain in taking this girl's history?” It will match any of the following answers: FAMILy history of BLEEDing. Are there any BLEEDers in the FAMILy? FAMILial BLEEDing history. Does any FAMILy member BLEED easily? Of course, it will also match “Is her BLEEDing tendency due to FAMILy?” The program responds to all these questions with “She denies that any of the family members ever had a bleeding problem.”

In the event that the student’s response matches nothing in the program, a statement of nonrecognition is printed, and the interchange is flagged for subsequent review by the author. After approximately 30 trial sessions, the richness of the vocabulary in the program increased to the point where over 90% of the responses were correctly recognized, while the delay of program execution remained nearly imperceptible. Since previous work has pointed out the difficulty of programming a computer to analyze the complex syntax of free text, English prose9,10 the adequacy of the key word approach seems important to the development of natural language computer programs.
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RESULTS

Experience With the Program in a Medical School Curriculum

The program was introduced in the second-year course in hematology at the Harvard Medical School as one of several optional teaching exercises available for the student. Students seemed tense during use of the program. They were anxious not to make mistakes, even when colleagues urged them to enter erroneous responses in order to explore the capacity of the program. During the first year, when response time was slow and when typewriter paper feeding was faulty, or when telephone linkage to the computer was interrupted, students occasionally terminated the session after minor delay. On the other hand, during the second year, when the equipment performance was flawless, nearly 75% of the students stated that they liked the program, and 37% preferred it over all other teaching methods. Fifty-eight percent of the students wanted the role of computer teaching expanded, and none wanted it discontinued.

In an effort to assess the effectiveness of natural language interpretation, we examined 200 consecutive student-program exchanges and found that approximately 1.5 answers/session, or 3.3% of all responses, were misinterpreted. Of these, all but one occurred in response to two loosely worded questions, subsequently rephrased, near the beginning of the session. An average of seven additional inputs/session (15% of all responses) were unrecognized as opposed to misinterpreted. Half of these were instances in which the student’s response was inappropriate for the question asked, and an additional one-third were attempts to rephrase previously unrecognized responses.

During the second year of operation, 52 student volunteers were alternately assigned either to the computer program or to the same material presented in a programmed instruction booklet. Whenever possible, the text of the booklet was identical to that of the program. Most of the material that was optionally available in the program was included in the appendix of the booklet. At the end of the computer teaching sessions the program questioned each student about his attitude toward the teaching method. Two days after the last session, all participants were given a ten-question, multiple-choice examination that covered the material presented but that did not include optional material. All 26 of the students assigned to the booklet and 19 of those assigned to the computer took the quiz. Eighty percent of all questions were answered correctly by the computer group, 70% by the control group. One question was answered correctly by all students; each of the other nine was answered correctly by a higher percentage of the computer group than the control group.

DISCUSSION

Importance of Natural Language Communication

If computer-based teaching is to serve the advanced student effectively, it must provide opportunities that are unavailable with textbooks or lectures. Computer-based teaching is distinguished from such alternatives by active
student participation and by the presentation of subject matter that can vary
dynamically with his needs. However, programs that offer multiple choice
or other restricted responses may discourage the student from developing
his own approach to problems. Furthermore, because the student never phrases
his own answer, misconceptions may remain hidden from the teacher who
cannot address them specifically. For these reasons, communication in natural
language may be an important attribute of programs designed to teach
clinical decision-making.

Even if educational objectives are precisely defined, there appear to be no
methods presently available that can compare the effectiveness of natural
language programs with those of other formats, such as multiple choice, or
with a programmed instruction booklet. In an effort to provide a choice, we
have programmed one of our cases as either free text, multiple choice, or a
mixture of each. When used in the mixed mode, the program shifts from one
format to the other after five of the ten specific facts have been taught. The
ten-question test can then be used to measure the teaching in each of the
formats. In our view, however, such an experiment is open to a variety of
serious criticisms. It cannot be proved, for example, that the free text and
multiple choice versions of the program were written with equal skill. Since
students take more time with the free text format, questions can be raised
about the practical advantage of this mode should it outperform the others.
To the extent that free text encourages the student to develop his own
approach to problems, it may encourage longer retention or offer some other
advantage that has not been defined or that cannot be measured. Finally, even
if one format could be shown to have a significant advantage over the other,
it would be difficult to generalize this conclusion to other programs designed
to teach hemostasis, to additional hours of instruction after novelty acceptance
has been dissipated, or to other course material.

CONCLUSION

It was the purpose of this study to develop a practical, low-cost method of
providing interactive, computer-based teaching of hemostasis using a natural
language technique. Experience demonstrates that the students like the
approach, that program can be easily written and modified, and that the
subject matter can be effectively taught. Whether this method of teaching
hemostasis, or other topics in hematology, offers a sufficient advantage over
other methods to justify the effort involved in constructing the programs and
the cost of operation cannot be determined from the data presented or from
other experiments that we can design. It is hoped, however, that our experi-
ence will be helpful to others in making policy decisions in this field.

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