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Abstract

A series of computer software tools have been developed which can help to discover clinical problems, and to develop diagnostic and management hypotheses based on relevant information in the medical literature. These tools are: the Problem-Knowledge Coupler, the Coupler Editor, the Knowledge Network, and the computerized Problem-Oriented Medical Record. In this paper the Problem-Knowledge Coupler will be described as it works for a typical office encounter to investigate a patient's presenting complaint, and then as it works for compiling history and physical examination data. The Coupler Editor and the Knowledge Network will be described in terms of their use in building Knowledge Couplers. Finally, the microcomputer version of the Problem-Oriented Medical Record will be illustrated as it is used to organize and record Coupler-based diagnostic and management decisions.

Patients expect their doctors to diagnose and manage their known problems and to discover ones they do not even suspect they have. They trust that the right questions will be asked and the right maneuvers reliably performed. Furthermore, not only do they expect the doctor to know all the appropriate diagnostic and management options, but also to choose for them among the options on the basis of their unique characteristics and needs. The unaided mind cannot meet such expectations. The myriad consequences of all the misguided attempts of the unaided minds of "credentialed" professionals to meet such expectations are not the subject of this paper. Rather, we want to describe a set of computer tools that can help lead us to, and help us choose among, options on the basis of the patient's specific problems and unique characteristics.

The principal software tool for coupling the relevant information from the medical literature to the patient's unique situation is the "Problem-Knowledge Coupler." The "Knowledge Coupler Editor" is available for building new Couplers for specific problems. The Knowledge Network, a tool used to structure an information base derived from the medical literature, is available to support Coupler building. Finally, a computerized Problem-Oriented Medical Record is available for implementing the Coupler-based guidance. The software was developed by Richard Hertzberg for the North Star Advantage (an 8 bit microcomputer with 64K bytes of memory). The software also runs on the IBM Personal Computer. Some of the software is available on the Apple II.

Use of these tools requires no computer training. The tools are best explained by describing typical encounters in the doctor's office. We shall first take a patient with a specific problem to show how how the Knowledge Coupler works, then show the routine for the discovery of problems and health maintenance. The Editor and Knowledge Network will be discussed in terms of building a specific Coupler. Finally, we shall show how the computerized Problem-Oriented Medical Record has been developed for the microcomputer to record the actions based on the guidance that Diagnostic and Management Couplers provide.

Use of the Knowledge Coupler for the Patient with a Specific Problem

The provider puts the appropriate Coupler diskette in his computer (along with a "System Disk"). (There may be as many as 8 Couplers on one diskette. In an orthopedic set, for example, one diskette contains Couplers for problems in the shoulder, the hip, the low back, the knee, and the leg and ankle.) The user hits one key to start, and a display like the following appears on the screen:

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+---------------------------------------------+
|                                            |
| Problem Knowledge Coupler System (TM)      |
|                                            |
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At Acute Abdomen

1: Upper and Lower Respiratory Complaints - Other ENT Complaints
2: Headache
3: Low Back Pain
4: Hypertension
5: Stopped Management of Essential Hypertension
6: Non couplers
7: System command processor

The user then types the letter or number to the left of the appropriate choice. In this case, we shall type 'A' and proceed with the problem, "Acute Abdomen." A series of displays then appears from which the user makes choices. As he
makes a choice an arrow appears in front of the text he has chosen. If he changes his mind, he just types the number of the choice again and the arrow disappears. He proceeds to the next display by typing 'N', for "N: Next question". A representative display is shown below:

### Acute Abdomen question 3

#### Location of the pain:

1: RLQ - right lower quadrant  
2: LLQ - left lower quadrant  
3: LUQ - left upper quadrant  
4: RUQ - right upper quadrant  
5: Epigastric and/or peri-umbilical  
6: Peri-umbilical combined with pain in iliacs or back  
7: Generalized/poorly localized  
8: Hypogastric  
9: Suprapubic and/or pre-sacral

**Ps: Previous question  Rs: Return  Ns: Next question**

The user makes choices that appropriately describe the unique patient. (No two patients make the same set of choices in the series; thus the use of the questionnaire can capture the uniqueness of each problem situation.)

When all the choices are completed, the user returns to the first display of the series, which has on it the choice:

C: Couple to the relevant literature

After the user makes the above choice, the following display appears:

#### 3. OBSERVED FINDINGS

- Adult 18-65 yrs old  
- H/O classification or vascular disease  
- H/O heart disease  
- Prior spells of cramping pain after eating  
- Earlier, older symptoms - 24 days before seeking help  
- Generalized abdominal pain  
- Pallor  
- Localized tenderness  
- Guaiac positive stools  
- Low grade fever - at onset or some hours after onset of pain

**Ps: Print results  Cs: Causes  Rs: Return**

The findings in the display above make up the constellation unique to this patient. By using the choice, "C: Causes", at the bottom of the screen, one can proceed to understand the situation further. The user types 'C' to bring up on the screen the following display:

#### 4. POSSIBLE CAUSES

- Mesenteric vascular insufficiency  
- Myocardial infarction  
- Appendicitis  
- Peptic ulcer  
- Acute appendicitis  
- Perforated ulcer  
- Small bowel obstruction

**Ls: Display cause information  Cs: Change reference display mode**

References not displayed

P: Print results  P: Findings  R: Return

By typing the number preceding any one of the above causes, the user can bring up a display like the following:

#### Suggested Causes: Mesenteric vascular insufficiency

- Findings present:
  - H/O classification or vascular disease  
  - H/O heart disease  
  - Prior spells of cramping pain after eating  
  - Earlier, older symptoms - 24 days before seeking help  
  - Generalized abdominal pain  
  - Pallor  
  - Localized tenderness  
  - Guaiac positive stools

- Findings not present:
  - Distention of the abdomen  
  - Epigastric and/or peri-umbilical pain

In the over 50 year old age group, abdominal atheroma and mesenteric thrombosis become increasingly important diagnoses to consider.

In mesenteric thrombosis, the most important early diagnostic feature is the severity of the abdominal pain relative to the paucity of the physical findings, and the unresponsiveness of the symptoms to narcotics.

The early symptoms (in about 50% of cases) of mesenteric thrombosis are pain (central, mild, cramping, accompanied by food), nausea and vomiting. The tenderness and distention occur late in the course and in the area of the involved gut.

**Ps: Print  Rs: Return**

Examination of the above display makes it apparent why the system is called the "Knowledge Coupler". Knowledge from the literature, that is, salient features of the diseases which are known causes of the problem at hand, is in the computer. When there is a "match" between a characteristic of the unique patient and a Finding for a given disorder, the Finding appears under "Findings present". The Findings in the machine for the same disorder with which the patient does not "match" are listed below as "Findings not present". Immediately below them are appropriate comments from the literature which further help the user decide how good the "match" is. If he decides he wants to pursue this suggested Cause further, he will look at the bottom of the screen and, if the choice "T: Tests" is present, he will type 'T'. Up will come a display with a suggestion as to the diagnostic test or maneuver that is appropriate.
The suggested Causes are listed in order of those with the highest absolute number of findings that match. Order is not based on a "percentage of the total for that disease". One should not give undue significance to the order of appearance. There is no substitute for taking the time to examine those possibilities which have a reasonable number of "matches", reading the comments, and letting the patient in on the process so that he can introduce further elements of his uniqueness, both qualitative and quantitative, which can be powerful in unravelling the problem. Patients are interested in what is a good "match", no matter how rare the disease might be. They are not necessarily interested in what is most probable for the population. Indeed, when they come to a physician, they hope he will find it if they have something unusual. Patients want to be treated as individuals and they fear being prematurely categorized -- "sounds like the flu, there is a lot of it going around". There is a basis for their fear; physicians do apply probabilistic information from the literature in direct proportion to their ignorance of the uniqueness of the patient's situation. The more information the physician has about the individual situation, the more apparent to him will be that situation's uniqueness, thus making it more likely that his every thought and action will be tailored to the individual's needs.

If the user has a question about the source of the information upon which the Coupler is based, he returns to the earlier display and types "C" for "Change reference display mode". After each Finding and Comment there will then appear a number which is keyed to a number in a booklet of abstracts (called "Documentation Items") provided with each Coupler. There reside the actual literature citations.

In summary then, the "Knowledge Coupler" harnesses the power of the computer to "remember" diagnostic and management options for problems and to "match" the patient to those options by systematically eliciting findings from patients and then electronically sorting and displaying them in terms of the diagnostic or management options, as you have seen above.

Using the Computer to Discover Problems
(Screening History and Physical Examination)

The patient uses the microcomputer directly to answer those history questions appropriate to him. The provider uses it to respond to questions about the physical status of the patient. The computer immediately takes the input from these encounters and displays or prints out several lists based on the unique set of answers provided by any given individual.

List #1 - responses requiring immediate management (e.g., severe chest pain or very low blood pressure)
List #2 - responses requiring reasonably fast attention but which do not indicate an emergency
List #3 - problems that require up-to-date
management but for which delays are tolerable (e.g., psoriasis)
List #4 - risk factors (e.g., smoking, no exercise, chemical exposures)

The various responses are printed out under the appropriate Systems Review headings as used in the traditional medical record.

Use of the Coupler Editor to Build Knowledge Couplers

The Coupler Editor, like the other problem-solving tools described here, requires no computer training or background. One merely needs to insert the proper diskette into the computer and proceed to make choices from the displays that come up on the screen. The main working display of the Editor appears as follows (with "Acute Abdomen") as the title of the Coupler being edited):

Knowledge Coupler Development

Coupler: Acute Abdomen

St: Build/edit/review QUESTION SEQUENCES (+ Coupler Control)
Sr: Build/edit/review QUESTIONS in master list
Fr: Build/edit/review Findings (+ Entity Relations)
Cc: Build/edit/review Causes
Mc: Build/edit/review Comments
Tc: Build/edit/review Tests
R: Return

The choices on this display provide the necessary framework for one to think about medical problem-solving and knowledge coupling. In effect, the display says to the user: Decide on a problem (or "Topic"), make a list of all the Causes for that problem, a list of Findings to be sought in patients that will include all the salient findings for each of the Causes, a list of Comments about Causes and Findings and Tests that was culled from your literature reading about the Coupler Topic, and, finally, a list of Tests or procedures which may be used to further delineate a Cause if the more simple Findings from the patient's history and physical prove to be insufficient as a basis for diagnosis and action. With these lists in hand, one can very rapidly build a Knowledge Coupler whose power lies in its ability to link electronically the authoritative thinking in an area of medicine to everyday problem-solving, which can then go on without inordinate dependence on the memory-based knowledge of costly, credentialed experts.

If we pick one of the choices of the above display, the "Causes" choice, for example, we get the display that follows:

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Whitehead says, we think in generalities but we display is intelligible to a user without computer on the Coupler builder at every step in the process. Difficulties, when arise, are more apt to have their roots in the confusion and the ambiguities in the medical literature from which specific information must be extracted. The demands placed on the Coupler builder at every step in the process often go beyond the demands placed on the average textbook writer who is free to use ambiguous prose, and to leave many consequences and connections unstated (if indeed they were ever explicitly worked out in the first place). As Whitehead says, we think in generalities but we live in detail. Knowledge Couplers either help us rigorously match the details of our everyday actions with the details of authoritative sources available for the problem at hand, or they rapidly confront us with the gaps in, and fallibility of, medical knowledge.

The Editor can become a vehicle for developing effective management tools. Routines can be established for emergency rooms, the front desk in a busy practitioner’s office, telephone answering services, and paramedical personnel. In these cases we are coupling daily actions of office personnel, not to just authoritative sources in the medical literature, but also to well thought-out approaches to the activities of workers in a busy environment. This assures coordination of effort, and a working situation less vulnerable to changes and variability of personnel.

The steps above give the reader an idea of how the tools we are describing can serve everyday workers in the medical field. This document does not allow space for the delineation of every step. Use of the tools is the best means to understanding the tools themselves and the philosophy that underlies their use.

The Knowledge Network and Documentation Tools

Sound problem-solving in medicine requires an ability to interact easily and effectively with the vast and complex stores of medical knowledge. Much of this complexity derives not from an infinite number of chemical and biological entities, but rather from an extremely large number of relationships among the entities. Pneumonia, cough, headache, brain tumor, and penicillin are examples of entities. ‘Pneumonia causes cough’, ‘penicillin treats pneumonia’, and ‘brain abscess causes headache’ are examples of relationships among entities. These relationships are of different types: cause relationships, treatment relationships, risk factor relationships, etc. They can be said to have a sense, or direction, and thus the entities and the links between them can be discussed in terms of “predecessors” and “successors”; for example, ‘pneumonia’ is a predecessor of ‘cough’, ‘cough’ is a successor of ‘pneumonia’. These relationships are the raw material from which Knowledge Couplers are built.

Since the relationships that are useful in solving one problem may also be very useful in unraveling another problem (the successors of pneumonia are useful in solving the problem of chest pain as well as that of cough), it is wise to keep a “Knowledge Network” as a cumulative, up-to-date resource for building Knowledge Couplers. Independent of building Couplers, these same “Knowledge Networks” provide an efficient mechanism for organizing and keeping track of journal reading and information (which can be stated in terms of entity relationships) picked up at conferences and elsewhere. Furthermore, they are useful in coordinating the efforts of workers in a given field of knowledge.

Traversing large networks to get all the predecessors or successors of a given Entity (e.g. all of the causes of back pain) is all but impossible if you are trying to work with a paper system. The computer makes such searches feasible. Seen below is the first display of the Knowledge Network developed by Richard Hertzberg for the microcomputer:

```
1: Traverse network
2: Develop/Maintain diagnostic entities
3: Edit display weighting
4: Review associated findings
5: Erase cause
6: Edit global entity number
7: Edit disease prognosis
8: Edit display weighting
```

It is apparent from the choices on this display that one can either add Entities, add relationships among Entities (“Facts”), or traverse the Network. Although all the steps cannot be reviewed here, we can imagine choosing the “Traverse” choice and seeing the display that follows (after specifying a “root entity”):

```
1: Traverse network
2: Develop/Maintain diagnostic entities
3: Edit display weighting
4: Review associated findings
5: Erase cause
6: Edit global entity number
7: Edit disease prognosis
8: Edit display weighting
```

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The Computerized Problem-Oriented Record for Microcomputers

Having used the tools described above to discover and organize the patients' problems for management and follow-up, it is important to keep an electronic record of the problems of each patient. We should be able to retrieve from that record the logic that underlies the pursuit of each problem and the results of that pursuit. Generation of the record and retrieval from it are easy for any user and no computer background is necessary. Retrieval across patients' records is also possible using this "network" of information on patients much in the same way as one retrieves information from the Knowledge Network. This latter capability enables a busy office to be a place not only of medical service but also one of clinical research and analysis.

Paper is not an adequate medium to convey the true sense of an electronic tool. This is particularly apparent when one tries to describe this computerized Problem-Oriented Medical Record. One must use it to develop a feel for it, and, except for the first display below, we shall not show computer displays, but rather give a short description instead. Those truly interested must actually use the Record system.

The first display is as follows:

R: Add to/Retrieve from a Patient Record
P: Add/Remove a Patient from the System
M: Develop/Review Medical Entities
S: System command processor

When the user first begins this sort of a record system he uses the bottom two choices to establish the medical and the structural vocabularies that characterize a particular practice of medicine. In this regard, it is helpful to think of the patient record as a small knowledge network full of important relationships and associations. There are certain structural units that organize and give meaning to many of the possible relationships, e.g., the Problem List, the Basis for the Problem Statement, the Status of the Problem, the Disability it leads to, the Follow Course parameters (symptomatic, objective, treatments), the elements of the Investigation, and Complications to watch for. Just as the physical structure of a library and its cataloging system become second nature as one uses them to store, organize, and retrieve information, so can the structural units of the record become second nature to the user. Without this

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R: Return

By typing the letter to the left of the appropriate choice, the user can enter the root entity from which he wants to start his search (e.g., hypercalcemia), the direction of the traversal (e.g., predecessors), the number of levels of the traversal (e.g., two levels, to include the predecessors of the predecessors), the types of entity relationships to be included in the search, and finally choose the traversal itself. For hypercalcemia, one gets the following display of the relationships to first level predecessors:

hypercalcemia
idopathic
infantile hypercalcemia (817)
periostitis, idopathic (819)
immobilization (821)
estrogens (722)
rhabdomyolysis (813)

etc.

(the list continues on to a total of 87 links in the current Network)

The Knowledge Network contains only the Predecessors and Successors - the skeleton of the relationships. On a separate set of diskettes one can keep the text of the Entity Relationships. This gives one an opportunity to store modifiers and useful descriptors and details from the reference source. The number associated with the text ('813' in the example below) corresponds to the number opposite the appropriate successor in the previous display.

Rhabdomyolysis (non-traumatic) may cause:

hypercalcemia (during diuretic phase of the acute renal failure - up to 13.9 did not last)

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Koffler A et al
Rhabdomyolysis with acute renal failure

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structure, coordinated care, efficient use of medical knowledge and corrective feedback loops in medicine become impossible.

In the electronic record, the user picks the structural element that concerns him and it appears on the screen with all of the relevant elements organized below it. He may then choose one of the four standard says of working on that "Current element"; i.e., retrieve all information that is 'under' it in the record, add something under it, delete it, or edit its text. If he chooses not to act on the Current Element, he can choose another element and "Add to" or "Retrieve" from the record under that element.

Conclusion

A series of computer tools have been developed that can help us discover patients' problems and develop diagnostic and management hypotheses that are based on the documented sources available for solving those problems. A computerized problem-oriented medical record system has been developed that allows us to test those hypotheses in a controlled and scientific manner. The total system is a guidance system for the care of individuals and for the study of the results of medical practice on populations of individuals.

Bibliography