The Physician's Workstation: Recording a Physical Examination Using a Controlled Vocabulary

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A system has been developed which runs on MS-DOS personal computers and serves as an experimental model of a physician's workstation. The program provides an interface to a controlled vocabulary which allows rapid selection of appropriate terms and modifiers for entry of clinical information. Because it captures patient descriptions, it has the ability to serve as an intermediary between the physician and computer-based medical knowledge resources. At present, the vocabulary permits rapid, reliable representation of cardiac physical examination findings.

Introduction

Practicing physicians needing timely information frequently find it unavailable. A recent study showed that clinicians are often unable to obtain reliable, up-to-date information regarding disease diagnosis and treatment, drug interactions and side effects, and previous medical records[1]. With the current explosion of medical knowledge, this problem will worsen. The good news is that computer-based tools are becoming available which assist with diagnosis[2,3], recommend therapy[4,5], check for drug incompatibilities[6], help formulate medical decisions[7], and search the medical literature[8]. The bad news is that each of these resources requires that the user convert clinical data into a form recognizable to the program and enter the information by hand, using application-specific terminology and commands.

An ideal solution to the problem of providing clinicians with access to computer-based information resources would be the entry of patient data into a central medical record and automating the transfer of this information among the various programs. A major requirement of such a remedy is that the data is recorded in a form that is not only machine-readable, but *machine-comprehensible* since the relevant concepts must be identified, distilled and translated into the vocabularies appropriate to the ancillary systems. Once the proper data has been selected and converted, the final communication with these other systems can easily be accomplished. In fact, programs such as Grateful Med[9] (for accessing medical literature) and the Medical Query Language[10] (for accessing medical records) fulfill the role of intermediary, albeit between a human and a program, rather than between two programs.

There are many ways to record clinical information to facilitate automated use of computerized medical resources. This paper examines some of the possibilities and describes a strategy with which we are experimenting.

Methods for Recording Clinical Data

There are several common approaches to automating clinical records (see *Figure 1*), none of which lends itself to integration with other systems. One method is to record the physicians' notes verbatim as narrative text. This serves to capture the content of the notes without loss of information; however, this form of data is notoriously resistant to abstraction and synthesis by computer programs and is unsuitable for translation to controlled vocabularies.

A second approach, currently in use in many hospitals, is to have a transcriber enter the clinical information using a controlled vocabulary taken from a reference book of a standard lexicon. There are several drawbacks to this technique. It is difficult for a standard lexicon to capture all of the nuances that might appear in a physician's note due to the richness and complexity of clinical vocabulary. Even if a comprehensive vocabulary is created, busy clinicians can neither be expected to memorize such an extensive terminology (even though it would be generally familiar to them), nor can they be expected to consult a reference dictionary to select appropriate terms when composing their notes. The transcriber is then required to translate (and decipher) the physician's narrative text. There is considerable opportunity for information to be lost or misinterpreted through this method.

We are currently examining the feasibility of a third method: providing the physician with an interactive workstation which allows selection of physical findings from a controlled vocabulary, obviating the need for memorization of the vocabulary, a reference dictionary or transcribers. We

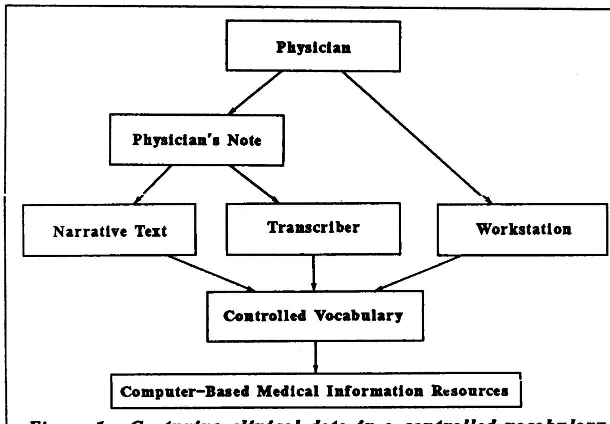

Figure 1: Capturing clinical data in a controlled vocabulary

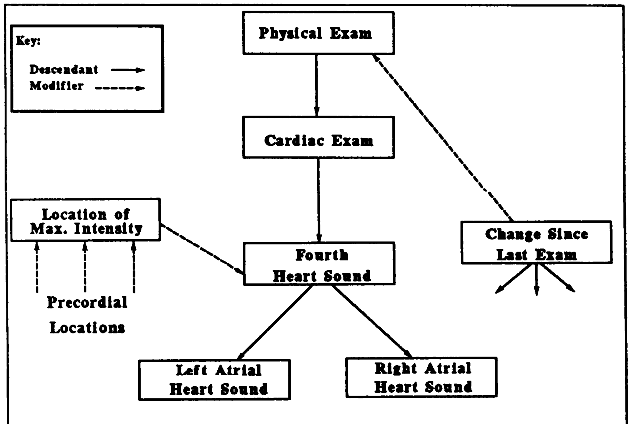

Figure 2: Hierarchies and modifiers in physical exam vocabulary

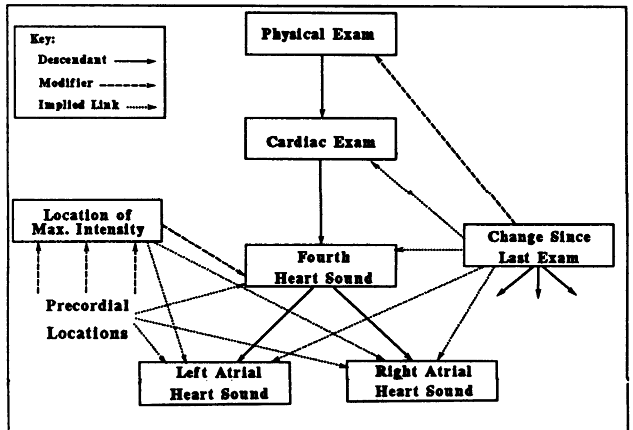

Figure 3: Example of inheritance of implied modifiers

do not expect that any standard lexicon can offer the range of expression capable with narrative text; however, we anticipate that as the controlled vocabulary becomes more sophisticated, the boundary between the controlled and uncontrolled portions of the record will shift favorably towards a more structured representation of clinical information.

There are three major problems to be addressed in the creation of such a workstation environment: an adequate vocabulary must be available, the user interface must be acceptable, and ample incentives must be offered for using the program. We have chosen the physical examination as an initial subset clinical information. We began with the selection of the terminology, reasoning that the structures needed for adequate representation would then help establish the requirements of the user interface.

The Controlled Vocabulary

A number of standardized medical vocabularies were considered for use in the workstation: the National Library of Medicine's (NLM) *Medical Subject Headings*[11] (used to index medical literature), the National Center for Health Statistics' *International Classification of Diseases with Clinical Modifications*[12], and the College of American Pathologists' (CAP) *Systematized Nomenclature of Pathology* (SNOP)[13]. All of these vocabularies have been very successful for their intended purposes, but none was constructed to represent physical examination data. CAP attempted to address this need by expanding SNOP to form the *Systematized Nomenclature of Medicine*[14] (SNOMED), to be used for encoding all clinical terminology. SNOMED is an extremely rich vocabulary, but it remains inadequate for the full representation of physical findings.

The NLM has also recognized the need for a standardized nomenclature for the medical record and has undertaken the development of the Unified Medical Language System (UMLS) The UMLS project will attempt to define the semantic and vocabulary requirements necessary to represent medical information. In theory, it will be possible to automate the translation of any lexicon into any other through the guidelines established in the UMLS. If this mission is realized, adhering to the conventions of the UMLS for our own vocabulary would confer considerable ability for automating access to computer-based information resources.

In the course of our work on the UMLS, we have developed a prototype vocabulary for representation of the physical examination[15]. Thus far, the language consists of physical findings (called terms) and adjective phrases (called modifiers) organized into hierarchical structures. *Figure 2* shows a small part of the term hierarchy dealing with the cardiac examination and a subset of the modifiers that can be applied. In this example, *Physical Examination* is shown with one of its descendants (*Cardiac Examination*) and one of its modifiers (*Change Since Last Examination*). *Change Since Last Examination* has several descendants which are not shown here. One of the descendants of *Cardiac Examination* is *Fourth Heart Sound*, which two descendent terms (*Left Atrial Heart Sound* and *Right Atrial Heart Sound*). *Fourth Heart Sound* is modified by *Location of Maximum Intensity* which, in turn, is modified by other modifiers such as *Increase* or *Lying Supine* (not shown).

Each term may have "allowable" modifiers assigned tc it by several means: they may be explicitly defined, they may be descendants of the explicitly defined modifiers, or they may be inherited from the parent of the term. A Modifier may also have modifiers. The term *Left Atrial Heart Sound* has no descendent terms nor explicit modifiers. However, as shown in *Figure 3*, a number of modifiers are implied using these rules for "allowable" modifiers.

The initial efforts have focused on the terminology of the cardiac examination. Terms were recruited from of the afore-mentioned standardized medical vocabularies, as well as from textbooks of cardiac examination. We validated the vocabulary by extracting cardiac examinations from seventy-five medical records (twenty-five each of medical inpatient, surgical inpatient, and medical outpatient) and then re-created them from our prototype vocabulary using the workstation interface (described below). The entire process took twenty minutes or 16 seconds per note and, with the exception of the phrase "No Pulmonary Embolism" (appearing in one surgical resident's cardiac examination note), all seventy-five notes were faithfully represented by the terms and modifiers in the vocabulary.

The User Interface

There have been a number of prototype and demonstration systems which were aimed at using computer systems to record portions of the physician's note. In several of these systems, health care providers entered their own clinical data by selecting from controlled vocabularies. Examples of previous work include a system used for recording physician notes in a hypertension clinic[16], a system for nurse practitioners in ambulatory care[17] and PROMIS[18]. Evaluations of these projects revealed several difficulties which had adverse effects on user acceptance.

Often, the physical limitations of the technology hindered user acceptance. Access to computers was sometimes hampered by system down-time and competition for use of computer terminals. The employment of light pens and touch screens required adaptation to new technology and introduced elements of confusion and arm fatigue. The style of the interface was also a source of difficulty by requiring a novel and not always enjoyable way of structuring problems. The result was that the system was sometimes perceived as playing a dominant, rather than a subservient role. In addition, the speed of the interaction was often felt to be too slow and the time required to complete the interaction was often regarded as excessive.

The controlled vocabularies used by the systems were often felt to be less than optimal; not all areas were covered with sufficient breadth and depth, necessitating the supplementation of the structured information with considerable narrative text. Integration of the systems with prior medical records and other systems involved in patient care (such as laboratory computers) was often inadequate.

The lessons learned in the above experiences have helped generate several design criteria. First, the technology employed should be widely available, reasonably priced, and provide a rapid time response. Second, browsing through the terminology should be as simple and direct as possible. Third, the program must be capable of allowing for the individual variations in style of the physician-users. Fourth, the appearance of the interface must be simple, straightforward, and uncluttered as possible. Fifth, and most important, the system must provide significant incentives to compensate the user for changing his or her recording habits by using the new technology.

Hardware Requirements

The physician's workstation runs on the Hewlett-Packard Vectra (an IBM-AT compatible machine) with a hard disk drive. The system makes use of color (or shading, on a monochrome screen) to convey additional information and to avoid cluttering the screen with labels. A mouse pointing device is used for the interaction, with a keyboard used only when entering narrative text. The program is written in ANSII Standard MUMPS to facilitate manipulation of the large vocabulary data structures. Overall, this environment offers an improvement over previous systems by taking advantage of recent technological advances.

Browsing Through the Terminology

Depicting all possible links in the manner used in *Figure 3* becomes unwieldy when the entire range of modifiers and descendent nodes is considered, even for this small subset of the vocabulary. The user will be concerned with finding the appropriate terminology quickly and will be less interested in the differences between internal structures such as descendants and modifiers. *Figure 4* shows an alternate way to depict the the links between terms and modifiers. In this arrangement the distinction between modifier and term becomes transparent, since the modifiers appear as descendants of the terms to which they refer. This type of structure would *not* be feasible in a reference book, since far too much space would be taken up by redundant inherited hierarchies of modifiers. However, this reduction to a hierarchical representation lends itself well to the workstation interface. The user is able to browse through the vocabulary with a minimum of effort and without requiring an appreciation of internal representations, simply by moving up and down the tree structure.

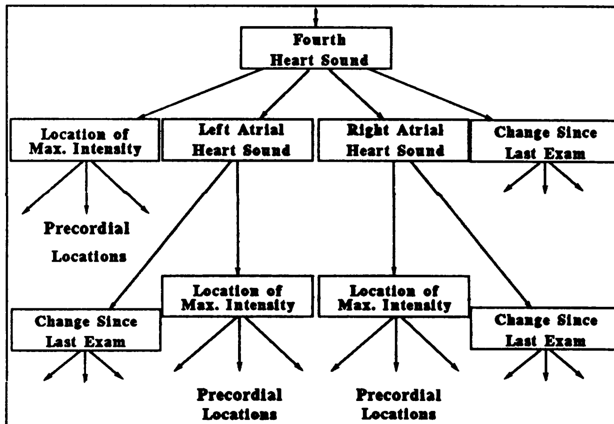

Figure 4: Reduction of implied modifiers to simple hierarchy

Customization

We have included several features in the workstation to accommodate the practices of individual clinicians. One important area where physicians differ is their preferences for particular terms. If a user objects to a specific term or modifier, the label for that finding may be changed, although its internal meaning is retained. For example, if the term "Liver Enlargement" is preferred to "Hepatomegaly", the user will be shown the latter, without interfering with the system's ability to translate the term for other systems.

Another area where physician preferences diverge is in the description of a normal examination. The set of findings which are present may be similar, but clinicians differ in their inclusion of absent findings. The workstation allows each user to decide the specific details of what constitutes the usual normal examinations of different organ systems, and retains these for inclusion into patient notes, when desired. Finally, the system allows each physician to specify desired links between items in the physical examination and items in other portions of the record. These links can then be used to help the physician organize the clinical information in ways best suited to his or her style of practice. For example, chief complaints can be linked to physical findings to allow the user to cluster subjective and objective data in meaningful ways.

Appearance of the Interface

Figure 5 shows a typical display. The left side of the screen shows the current labeling of the function keys (their arrangement is analogous to their layout on the keyboard), while the remainder of the screen depicts the user's current level in the vocabulary, the ancestry of that level, and the terms and modifiers selected at and below the present level.

The asterisk (*) on the right is the mouse cursor. The user selects function keys, moves through the vocabulary structure, and performs scrolling operations with the mouse. The mouse interface was chosen because of its widespread acceptance among users at all levels of computer experience.

In this example, the user is looking at the modifiers for the term *Heart Murmur*. Their ancestry (at the top of the screen) is *Heart Murmur* and *Cardiac Examination*. The plus signs (+) indicate that there are terms and/or modifiers below each item. The user can descend the vocabulary hierarchy by selecting a plus sign with the mouse.

The user selects items with the mouse to indicate that a physical finding is present, causing the words on the screen to change from black to white. For example, the display shows that the user has chosen the modifier *Systolic* and the child of that modifier, *Midsystolic*. Choosing a previously selected term a second time has the effect of negating the term. For example, selecting *Fourth Heart Sound* a second time would change it to *No Fourth Heart Sound*. Choosing a selected term a third time deletes it's selection, returning it from white to black.

If desired, the user may indicate that an item should be linked to narrative text through the use of a function key. Another function key allows the user to "duplicate" an item. For example, after describing a midsystolic heart murmur, the user could cause *Another Heart Murmur* to be added to the list and then modify it with *Early Diastolic*.

Many iterations have occurred in designing the style of the interaction and the screen layout. The result is a display which accomplishes many tasks with a minimum of overhead, the goal being to present a screen that is lucid and logical. The user may see, at a glance, the path to the portion of the vocabulary being explored and the findings selected at and below the current level. The purposes of the function keys are prominently displayed.

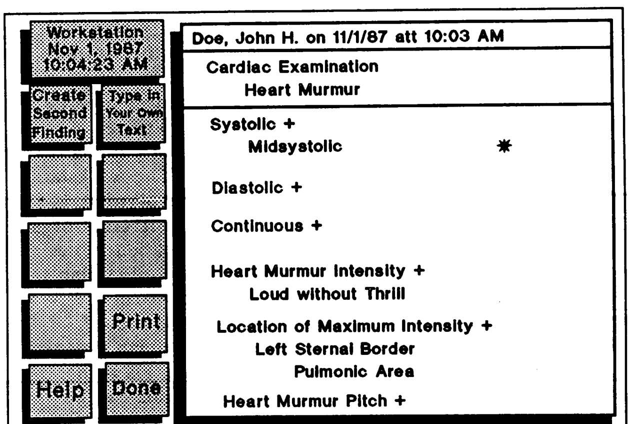

Figure 5: Sample workstation display

Incentives

Since the introduction of a new process is likely to be met with resistance, the advantages of the system employed must be substantial and readily apparent. It is unlikely that any system could compete with the ease and flexibility of a pen and paper. The computer can offer legibility, completeness and improved organization, but it is apparent retrospectively. For incentives to work their advantages must be immediate. Our system offers several inducements.

First, previously recorded data is instantly available. Since the data is in a controlled vocabulary, indexing the medical record is simplified, improving the potential for retrieving clinical information and incorporating it into subsequent notes. For example, findings from a prior examination are carried forward with a single key stroke, to then be modified, rather than re-entered.

A complete physical examination usually reveals many findings which are considered normal. While the statement "normal cardiac examination" conveys little information about precisely what was observed, the inclusion of each normal finding (first heart sound, second heart sound, no murmur, no rub, etc.) in a hand-written note is far too tedious. Our system allows the user to specify normal examinations in advance as sets of findings. Then when entering a physical examination, those sets which are appropriate can be incorporated, en masse, into the record.

We are developing an optional method of recording data in a problem-oriented format which encourages and facilitates the recording of an appropriate physical examination for a given problem. The system developer defines a protocol consisting of the problem name and all the pertinent physical findings that might be recorded about that particular problem. When a user later notes a specific problem while recording information about a patient, the system will bring to the user's attention the terms which might be pertinent in the physical examination of a patient with that problem. For example, a protocol for *Sore Throat* might list *Splenomegaly* as a potentially relevant physical finding. When the user notes that a patient has a sore throat, the system will display *Abdominal Examination* in color. If the user selects the abdominal examination, the term *Spleen Palpable* will also appear in color. In this way, the system reminds the user of pertinent information which might also be recorded, without dominating the interaction. The user is free to explore or ignore colored items in a list.

Discussion

There are several problems which must be addressed in any introduction of a new clinical information system. The method of interacting with the system should attempt to reflect current practices in order minimize disruption, while offering clear advantages over the manual record. In the case of recording the physical examination, the computer interface must be easy to use and allow the selection of findings in a style similar to that used in the written record. In addition, the vocabulary must be acceptable for capturing precise meaning while allowing freedom of expression.

The workstation allows the user to record the physical examination in a manner that is essentially the same as a written record. It also offers several clear advantages. First, the problem of medical record legibility[19] is resolved. Second, the records have the potential for being more complete by simplifying the entry of negative findings, allowing the inclusion of previous findings (which can then be modified, rather than completely regenerated), and the selection of a (user-specific) set of findings which constitute a set of normal findings (e.g., "Normal Cardiac Examination"). With these features, the user may compose more complete examinations with a minimum of extra effort.

As the workstation is expanded to include other portions of the medical record, the potential usefulness of the system will rapidly increase. For example, by adding medications to the vocabulary, specific treatments could be linked to specific problems, using problem protocols. It would then be simple to have the system print prescriptions and patient instructions, based on treatment selections. Such a simple operation has the potential to saving time and improve medical care. Because the controlled vocabulary is based on the Unified Medical Language System, patient data may be transferred to systems which recognize this lexicon. Automating the transfer of patient data to these systems will allow the timely retrieval of medical information.

In addition, data from medical records created using a controlled vocabulary is then available for systematic data extraction as a clinical medical knowledge base[20]. Clinical knowledge contained in individual records can be accessed in a way that can enhance general medical knowledge.

Admittedly, the portion of the clinical record upon which we have initially focused is a small subset of the medical vocabulary. Also, the physical examination vocabulary is one of the more structured, and hence easier to implement with a computer-based hierarchy. We recognize that such tasks as the recording the present illness will offer new challenges; however, we believe that much of the style of interaction which we have developed for entering the physical examination will prove suitable as we turn our attention to other portions of the medical record.

Conclusion

At present, little is known about physician acceptance of either the vocabulary or the interface provided by the workstation. However, we believe that our approach has the potential for a system that will find user acceptance through its ease of use and the incentives it will offer. The full benefits of this system will not be realized until the UMLS has developed to the point where other computerized medical information sources can be integrated, in order to automate the retrieval of information relevant to a clinical case.

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