Representation of clinical practice guidelines through an interactive World-Wide-Web interface

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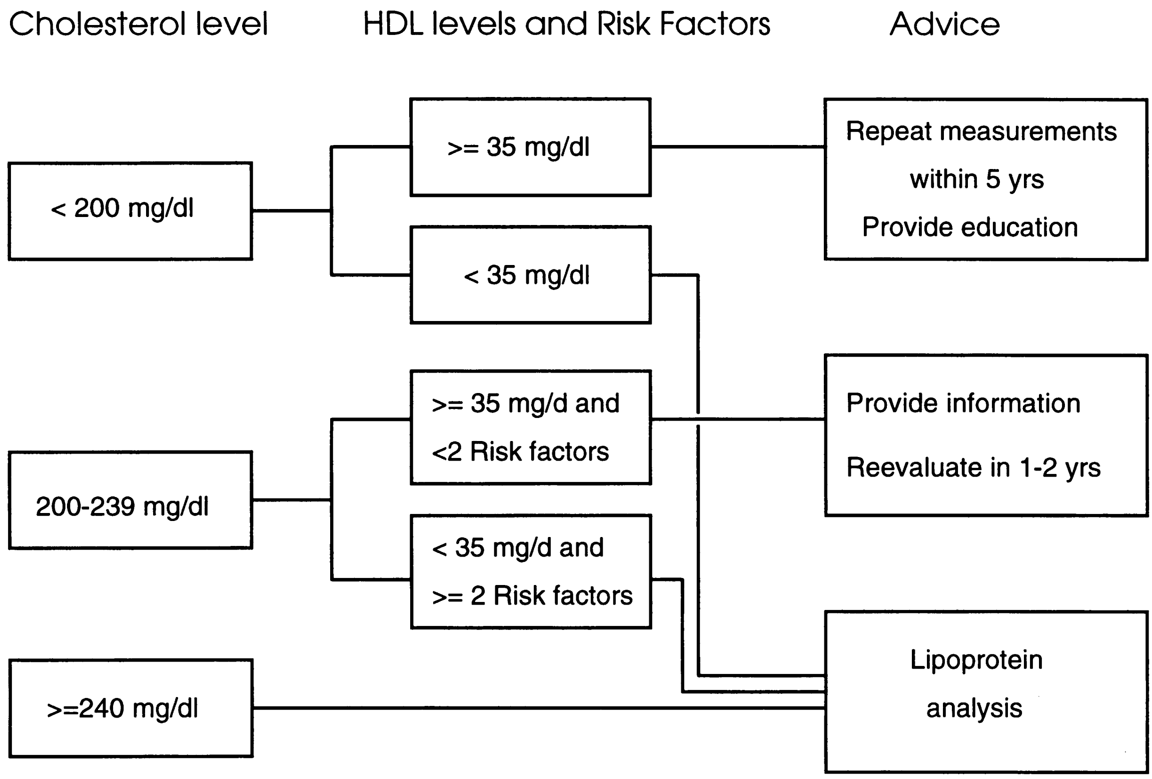
The widespread utility of clinical practice guidelines is greatly dependent on the ease with which they can be accessed, used, and applied. Because it supports hyperlinking and is widely accessible, the World-Wide Web is a medium that is well suited for browsing through guidelines. We have developed a process for implementing algorithmic guidelines into a graphical format that allows the user to browse these guidelines in an interactive fashion. The guidelines we used were already in or could be transformed to an algorithmic format that lends itself well to analysis with decision table techniques, which in turn permits a fairly straightforward conversion into a graphical representation. The results of this process allow a user to browse a particular guideline algorithm and to visualize the traversed parts of the algorithm by flowcharts. Our first experiences with this method of representing a few sample clinical practice guidelines have been encouraging, and we hope to extend this method to other guidelines.

INTRODUCTION

Many clinical practice guidelines are available and promoted for an extensive range of clinical problems. Guidelines can help clinicians decide on appropriate health care, improve clinical outcomes, and reduce costs [1-3]. In a literature review Grimshaw [4] demonstrated that there were significant improvements in the process of care following the introduction of clinical guidelines. Compared with the efforts that are going into the process of guideline development, much less attention has been given to the conditions for their successful implementation, dissemination, and practical application in real practice settings. Guidelines are not used as widely as could be expected, and studies have shown that clinicians frequently fail to follow published recommendations. Lack of awareness, unavailability, disagreement with the guidelines, and the inability to apply these guidelines conveniently to a particular situation all contribute to under-usage of published guidelines [1,5,6].

Most guidelines are still paper-based narratives, but there have been attempts to make computer-based guideline algorithms. Studies have shown that the implementation of computerized guidelines in clinical settings has increased physicians' compliance with guidelines [8,9]. Computer-based guidelines are usually implemented within the context of specific hospital information systems, where the level of integration varies from being a means of reference [10] to interactive clinical reminder systems [8,9]. A World-Wide-Web representation of clinical guidelines would have the distinct advantage of being widely available across nearly every platform to nearly anyone with an internet connection, and the use of hyperlinking in this medium can inherently optimize the access to existing clinical guidelines. The Agency for Health Care Policy and Research (AHCPR) has made a web-based interface to their guidelines, but these are only direct translations of their text-based narrative guidelines. The utility of a web-based interface to these guidelines can be enhanced by using interactive data-entry to direct the user to the next stage in the guideline on the basis of data entered and by the addition of elements such as flowcharts that can display how the user arrived at a particular point in the guideline algorithm. Other graphical elements can be used to highlight important clinical data, tables, or figures. The development of a generic process for the transformation of a clinical guideline into a web-based representation has also been undertaken by Barnes [11], although the emphasis in that work lies more on the development of a system architecture for distributed clinical reminder and practice guideline decision support systems.

Figure 1. NCEP cholesterol guideline flowchart



METHODS

The Expert Panel of the National Cholesterol Education Program (NCEP) has published widely known guidelines on the detection, evaluation, and treatment of high blood cholesterol in adults [12]. Our approach to transformation of various guidelines will be illustrated with the NCEP guidelines, but we are also working on several other guidelines (e.g. the management of infants and children with fever without source[13] and the neurologic management of dizziness[14]). We chose only guidelines that either contained clearly defined clinical algorithms or out of which such algorithms could be extracted. These algorithms are usually represented by decision trees or flowcharts in which the nodes represent either data, actions, or decisions evaluated sequentially.

The first stage of the clinical evaluation of high blood cholesterol in adults without evidence of coronary heart disease (CHD) is shown in figure 1. In this initial stage, classification is based on blood cholesterol, HDL level, and the number of risk factors. Classification must be determined before proceeding to the next stage in the guideline algorithm. The risk factors are age, a family history of premature CHD, smoking, hypertension, diabetes, and the HDL level, where an HDL level of <35 mg/dL is counted as a positive additional risk factor whereas an HDL level of >60 mg/dL is regarded as a negative risk factor, and thus has to be subtracted from the number of risk factors.

After identifying the various stages in a guideline algorithm, we map the conditions for each particular stage of the guideline algorithm to a decision table for that stage. A decision table is a matrix of rows and columns that associates a set of conditions or tests with a set of actions. Initially, all the decision variables were listed (blood cholesterol level, HDL level, and the number of risk factors) and the possible actions that could result (advice sets 1-3). All possible values for every decision variable were listed (e.g., for blood cholesterol these would be : low, <200 mg/dL; medium, 200-239 mg/dL; and high, >240 mg/dL). Using techniques developed by Shiffman [15,16] facilitated logical analysis of the guideline algorithm, although this part did not reveal any logical inconsistencies.

Every decision table can be converted to a relational database table as shown in figure 2, in which the primary key consists of an ID for every particular

Figure 2. Relational Database table for NCEP Cholesterol Guidelines (initial stage)

Combinr	BCHOL	HDLL	Riskchoice	Outcome	Flowchart
1	LOW	LOW	LOW	3	flow13.html
2	LOW	LOW	HIG	3	flow13.html
3	LOW	HIG	LOW	1	flow11.html
4	LOW	HIG	HIG	1	flow11.html
5	LOW	SHIG	LOW	1	flow11.html
6	LOW	SHIG	HIG	1	flow11.html
7	MED	LOW	LOW	3	flow23.html
8	MED	LOW	HIG	3	flow23.html
9	MED	HIG	LOW	2	flow22.html
10	MED	HIG	HIG	3	flow23.html
11	MED	SHIG	LOW	2	flow22.html
12	MED	SHIG	HIG	3	flow22.html
13	HIG	LOW	LOW	3	flow33.html
14	HIG	LOW	HIG	3	flow33.html
15	HIG	HIG	LOW	3	flow33.html
16	HIG	HIG	HIG	3	flow33.html
17	HIG	SHIG	LOW	3	flow33.html
18	HIG	SHIG	HIG	3	flow33.html

Explanation of database fieldnames
Combinr: Primary key for combination of conditions.
BCHOL: Blood cholesterol level, with values LOW (<200 mg/dL), MED (200-239 mg/dL), or HIG (>= 240 mg/dL).
HDLL: HDL level with values LOW (< 35 mg/dL), HIG (35-60 mg/dL), or SHIG (> 60 mg/dL).
Riskchoice: Values indicate whether number of riskfactors < 2 (LOW) or >= 2 (HIG).
Outcome: Values indicate what outcome should be chosen in condition combinations (e.g. outcome 3 = lipoprotein analysis).
Flowchart: Flowchart filename.

combination of values. The other database fields consist of the values of the decision variables and outcome values. The information for navigation of the guideline algorithm can thus be stored in this format. We evaluated the various guideline decision trees and produced flowcharts for each. Taking each flowchart as a template, we made overlays for every possible combination of nodes. These overlays graphically represent the particular sequence of nodes that have been chosen by the user when navigating the guideline algorithm. Each flowchart is linked to the primary key in the database table.

Common gateway interface (CGI) scripts were written for every guideline. While the user is navigating through guideline web-pages on a client browser, CGI scripts on the web server are called when data are submitted. The CGI scripts make repeated SQL queries through a relational database-management system. By looking up the relevant information in database tables, the next appropriate step in navigating the guideline and the correct flowchart to display can be determined.

For initial implementation we used Visual Basic scripts and a MS-Windows based web server. For reasons of compatibility, part of the work was later ported to Perl scripts executed by the NCSA HTTPD-server on Sun workstations. The database management system we used was mSQL (mini-SQL), which is freely available as shareware and for which Perl extensions exist. For generation and analysis of decision tables we used Shiffman's [15,16] KADET (Knowledge in Augmented Decision Tables) software.

RESULTS

At present, users choose one of the listed guidelines to navigate. The first page of most guidelines presents some clinical background on the specified subject. Users are then prompted for data entry (e.g., risk factors in the case of the cholesterol guideline). Based on the submitted data, the CGI scripts dynamically create a new HTML page with the results, clinical suggestions, and additional data entry forms if necessary. Links to flowcharts are dynamically created at every stage so the user can refer to and view the sequence of steps that has been followed. Initial reactions have been positive and encouraging. Most clinicians viewed this as a convenient and transparent way of navigating through a guideline. A sample of the cholesterol guidelines can be viewed at: http://dsg.harvard.edu/public/guidelines/cholesterol/chlintun.html

DISCUSSION

Only practice guidelines that are organized in an algorithmic fashion will be amenable to the approach we have used. In order to computerize these guidelines a knowledge representation has to be chosen. Many different knowledge representation formalisms have been used to encode practice guidelines. The NCEP guidelines have been encoded using first-order logic systems (PROLOG), frame-based representation systems (CLASSIC), and production rule systems (CLIPS) [11,17]. We are using relational database tables that are directly derived from decision tables. The use of decision tables provides an overview of the rule set, allows for easier optimization of guideline rule sets, helps determine whether a rule set is logically consistent, and recognizes whether ambiguous rules are present [15, 16].

In the near future we expect to automate the creation of flowcharts from guidelines and to generate computerized versions of other clinical guidelines with a web interface. The guideline knowledge representation itself will be subject to considerable change, since we will be trying to arrive at a guideline representation that can be used for algorithmic representations and for state models such as those in the GEODE project [18]. Different guideline knowledge representations between different institutions could be integrated if they coexisted in an architecture that would support organizing integration of these different systems. The MBTA (Modeling Better Treatment Advice) practice guideline system has been proposed as such an architecture [11].

The representation of time in computerized care guidelines [19] will become an especially important issue when these guidelines are more directly incorporated into clinical practice information systems, functioning as clinical reminder sets that are customized for individual patients. At present we are concerned with an event-driven, rather than an interval-based, time representation.

CONCLUSIONS

A consensus on how to define, develop, and assess the effectiveness of guideline implementation in clinical practice must be reached, whether or not these guidelines are published and used in an electronic format. It is only when clinicians are aware of, have easy access to, and feel compelled to regularly refer to practice guidelines that clinical guidelines are actually used. The development of a process that is generally applicable to algorithmic guidelines for creating interactive and graphically oriented Web-based representations of these guidelines will be a step in that direction.

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