

Evaluation of a System to Identify Relevant Patient Information and Its Impact on Clinical Information Retrieval

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Concept-oriented views of electronic medical records are desirable, yet difficult to create. We have developed a system that creates concept-oriented views by identifying relevant patient information, however, previous such systems have received little evaluation. We present here an evaluation of our system's ability to identify relevant patient data and generate concept-oriented views, along with the clinical impact of the generated views. The evaluation was carried out in three parts: First, using physicians and medical literature as gold standards, the system's sensitivity and specificity in identifying relevant information were measured. In some areas, the system demonstrated sensitivity comparable to that of physicians. Second, concept-oriented views were compared with original records and shown to contain significantly less non-specific information. Third, physician volunteers, when answering questions about patient cases using the concept-oriented views and traditional source-oriented views generated by the system, showed a significantly greater accuracy in information retrieval using concept-oriented views.

INTRODUCTION

Prior to the widespread use of electronic medical records (EMRs), information overload in the form of thick and often disorganized paper charts had already been recognized as a problem for clinicians.^{1,2} Although EMRs are gradually replacing paper records, the amount of available clinical data continues to increase.³ While clinicians need access to the entire patient record, they often seek answers to specific questions and wish to browse certain subsets of data.^{4,5} The increasing volume of available information can make it both impractical to browse all data and difficult to search for specific data subsets.^{1,2,4}

We refer to these subsets of data as *views*. Prior studies have shown that certain pre-defined views can reduce information overload and improve information retrieval efficiency.⁶⁻⁸ Traditionally, views have been organized by *where* and *when* the data are collected. We refer to these as *source-oriented and time-oriented views*. Alternatively, views can be organized

by clinical concepts, such as diseases or organ systems, and these have been referred to by Dore et al. as *concept-oriented views*.⁹

While highly desirable, concept-oriented views can be difficult to generate. The major obstacle is identifying the relevant data for a given concept of interest. In generating problem-oriented views¹⁰, for example, the manual linking of each data element to different patient problems was found to be prohibitively arduous.¹¹

Automating the generation of concept-oriented views would make them readily available. However, because of the amount of knowledge required to identify relevant patient data, this has rarely been attempted. One significant exception was the development by Tang, et al. of a pilot system that could identify clinical data related to certain patient problems.^{12,13}

Previous research has shown that concept-oriented views may improve information retrieval and medical decision making. Notably, a quantitative evaluation of different views of medical narratives for information retrieval by Tange et al. demonstrated the value of problem-oriented and organ system-oriented views.¹⁴ Also notable is the work of Suermondt, et al. showing that it is possible for computers to identify relevant data and generate views.¹² However, the relevance of data identified by computer-automated methods and the impact of providing concept-oriented views generated from such identification has received little evaluation.

We have developed a system for relevant patient information identification and concept-oriented view generation. This paper presents our evaluation of the utility and clinical efficacy of the system.

BACKGROUND

At Columbia University, we have designed and implemented a multiple view generation system for use with the New York Presbyterian Hospital (NYPH) EMR. The primary function of the system is to generate concept-oriented views, although it is equally capable of generating traditional views oriented by clinical ancillary departments (source-

oriented views) or by data collection time (time-oriented views).¹²

Given a user-selected concept of interest, the system retrieves relevant coded clinical data and presents it as a view. For example, if a physician selects myocardial infarction as a concept of interest, the system will locate information such as cardiac enzyme test results, cardiac medications, or previous hospitalizations for ischemic heart disease, and return the results to the user in integrated display. The system currently supports views for 9 major classes of medical concepts (including over 40,000 individual concepts), such as patient problems, anatomical entities, and chemicals.

The system design is knowledge-based and generalizable, employing four major categories of knowledge resources: existing knowledge bases, on-line information sources, domain experts and medical literature. The knowledge in the system is represented in both a semantic network and in rules. The key relevant data identification function is accomplished by a rule-based traversal of the semantic network. The semantic network employed here is the Medical Entities Dictionary (MED), containing the NYPH vocabulary as well as classification and definition knowledge.¹⁵ The majority of additional knowledge was acquired by automated methods from external resources, in particular the Unified Medical Language System (UMLS) and the DXplain decision-support system.¹⁶⁻¹⁸

METHODS

This study evaluated our system's ability to identify relevant patient information and the impact of the resulting views on clinical information retrieval. The evaluation was divided into three parts: 1. Quality of relevant information identification -- to measure the sensitivity and specificity of relevant information identification in certain clinical contexts such as hypothesis validation or disease management; 2. Information overload reduction -- to assess the degree of reduction of the amount of information in the concept-oriented views compared with the entire records; 3. Effect on information retrieval -- to determine if there are any advantages to using the concept-oriented views compared to traditional views in retrieving clinical information.

Quality of relevant information identification

To measure sensitivity and specificity in identifying patient information related to concepts of interest, we used lab tests and medication orders as patient information and diseases as concepts.

A set of 653 patients was randomly selected from all patients with hospital visits between September 1996 and September 1998. Their lab tests, medications, and diagnoses during this time period were retrieved for use as the patient data set.

As our gold standard for relevant medications, we used the Micromedex drug index, a widely used knowledge base of drugs and clinical review articles.¹⁹ From the set of diagnoses, 7 diseases (*pulmonary embolism, tuberculosis, hypertrophic cardiomyopathy, acute renal failure, heart failure, pancreatitis, and multiple sclerosis*) having review articles indexed in Micromedex were randomly selected. For each of the 7 diseases, all drugs mentioned in the disease reviews were extracted, regardless of comments on their efficacy.

Gold standards for relevant lab tests were established by a survey of 6 physicians, and, given that the relevance between diseases and lab tests can vary in the context of disease diagnosis versus management, we established a gold standard for each context. From the set of diagnoses, 5 diseases (*sickle-cell anemia, congestive heart failure, coagulation defects, diabetes mellitus, and acute pancreatitis*) discussed in *Harrison's Principles of Internal Medicine* were randomly selected.²⁰ A list of candidate lab tests was compiled by taking the union set of all potential lab tests identified by a physician expert, using *Harrison's Principles of Internal Medicine* for each of the 5 diseases. The surveyed physicians were given two questionnaires, each containing a matrix of the candidate tests and 5 diseases. On one they were asked to identify tests they might order to confirm the diagnosis of each disease, and on the second to identify tests useful for the management of each disease. They were also asked to suggest any tests that were not included in the candidate list. Tests were considered gold standard for relevance when 4 out of 6 physicians agreed. A semi-automatic translation process was used to map the terminology of the identified lab and drug gold standards to the controlled coding concepts of our patient data set.

For each disease, we used both the gold standards and our system to identify relevant medications, diagnostic lab tests, and management lab tests in the patient data set. Sensitivities and specificities were then computed by comparing the results.

In addition, we identified relevant lab tests based on each physician's individual opinion and tested them against the gold standards. The sensitivities and specificities of the physician's selections were then compared to those of the system to see if a significant difference existed.

Information overload reduction

Using the data set created for the relevant information identification in the previous section, we randomly selected twenty-one diseases from the 1094 diagnoses in the data set and used our system to identify relevant lab tests and medications for each disease. The average number of lab tests or medications in each disease-specific view per patient and the total number of lab tests or medications per patient were calculated. These were used to measure how much information the disease-specific views contain compared with the whole data set. Patients with no lab tests or medication orders were excluded from the calculation.

Effect on information retrieval

The effect of using concept-oriented views on several aspects of information retrieval was evaluated. In this paper we will only discuss methods and results related to the accuracy of information retrieval.

We selected three patient records, having moderate size and complexity, for which we formulated questions necessitating patient information retrieval. The questions were designed to accurately reflect questions physicians may have in clinical settings based on information needs studies in the literature and on our own observations.^{5, 21, 22} The questions were also designed to elicit short and unambiguously correct answers. For example, a question regarding a patient discharged on digoxin asked "what was the latest digoxin level?"

Thirteen physician volunteers were presented with a brief description of each case and then asked to answer questions using our system to retrieve patient information. For each case, physicians were instructed to use either the traditional department-oriented views or concept-oriented views.

Block design was applied to ensure that department-oriented views and concept-oriented views were used an equal number of times for each case and that a physician never encountered a case twice.

Written responses were graded relative to the gold standard answers, with a correct answer scored as '1' and incorrect answer as '0'. A t-test was performed to compare the accuracy scores achieved with each view.

RESULTS

Quality of relevant information identification

Table 1 and Figure 1 show the sensitivities and specificities of the system and individual physicians in identifying relevant lab tests and drugs. Although the specificities of the physicians were significantly better, the difference in sensitivities was not statistically significant.

Table 1. Sensitivities and specificities of the system and individual physicians in relevant patient data identification

Identified By	Data Type	Clinical Context	Avg. Sens.	Avg. Spec.
System	Lab	Diagnosis	86.2%	74.8%
System	Lab	Management	55.2%	76.7%
Physician	Lab	Diagnosis	80.8%	94.5%
Physician	Lab	Management	82.7%	91.6%
System	Drug	N/A	80.9%	80.0%

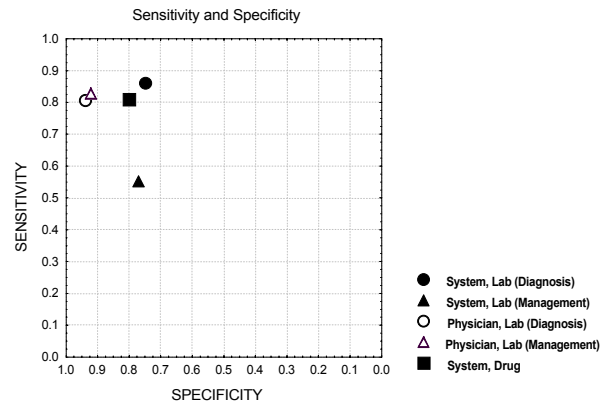


Figure 1. Sensitivities and specificities of the system and individual physicians

Information overload reduction

Concept-oriented views, on average, only contain a small fraction of all information in patient records. However, the amount of information in the views varied significantly from concept to concept and patient to patient. Table 2 shows the average number of tests and drugs for each patient in total and in a view.

Table 2. Average number of tests and drugs for each patient in total and in a view

Average Number Per Patient	Lab Tests	Drugs
Total	170.5	20.6
In Each View (Percentage of the Total)	24.0 (14.1%)	3.2 (15.8%)

Effect on information retrieval

As shown in the Figure 2, the mean accuracy score when using concept-oriented views is higher than department-oriented views, indicating that physicians answered questions more accurately when using concept-oriented views. A t-test of independent samples showed the difference in scores between groups using the two types of views to be statistically significant. ($p < 0.05$)

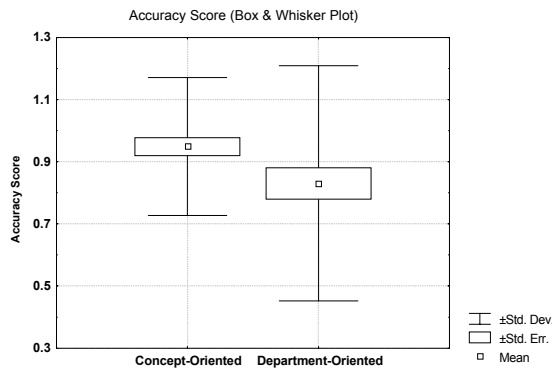


Figure 2. Score of accuracy when physicians use concept-oriented vs. department-oriented views

DISCUSSION

We have sought to evaluate a system for identifying clinical information in EMRs to produce concept-oriented views, along with the clinical impact of the generated views. This evaluation demonstrated the system's ability to identify relevant clinical information and to generate concept-oriented views. In identifying lab tests for diagnostic use and in identifying medications, sensitivities of the system exceed 80%. Given that physicians' sensitivities in identifying lab tests are also in the 80% range, the system's ability to find relevant information can be considered comparable to physicians. The specificities of the system (74% - 80%) are consistently lower than the specificities for physicians (92% - 95%), which means that physicians are better at ruling out irrelevant information. However, since 85% of the information is already being filtered out

from each view, the system's specificity is not a critical problem.

These results seem particularly encouraging because we employed a knowledge-based approach in the system development and most of the knowledge was either taken from existing knowledge bases or acquired with automated methods. This evaluation validated our effort in knowledge reuse and knowledge acquisition. It also confirmed the value of our knowledge sources.

The evaluation helped us recognize areas that need improvements as well. For example, the system did not do as well in identifying lab tests for disease management which directly reflects the weakness of our knowledge base in that area. We found that we should explore more knowledge sources. Knowledge from new sources may complement sources currently being used and thus improve the sensitivities, while it may also help to improve specificities if used to corroborate knowledge already acquired.

Information overload is the problem that initially inspired us to develop the system. Shown to contain much less information than complete records, the concept-oriented views could be used to reduce information overload when users are interested in retrieving information on particular topics.

Using concept-oriented views, the accuracy of physician information retrieval was improved compared with using traditional department-oriented views. This positive finding resulted from the ability to cluster relevant information and reduce the overall amount of information for review. Because the evaluation questions given to physicians were questions they would be asked during routine practice, we believe that our findings do have implications for actual clinical settings.

However, it is not our intention to claim that concept-oriented views are superior to other views. On the contrary, we believe that different types of views complement each other. Considering the complex nature of medical practice, an ideal system should be able to offer multiple types of, or hybrid, views.

CONCLUSION

Our evaluation demonstrated that concept-oriented views can be generated and can benefit information retrieval. Our system was shown to be able to identify relevant patient data with sensitivities that, in some areas, are comparable to physicians. The concept-oriented views contain significantly less non-specific information than the whole records and can be used to reduce information overload. We also

showed that the accuracy of physician information retrieval improved when using the concept-oriented views generated by the system.

ACKNOWLEDGMENTS

The authors thank the physicians who participated in the evaluations. The authors also thank Dr. Octo Barnett for his generous help in providing DXplain knowledge, and Dr. Gai Elhanan, Dr. Osama Alswailem, Dr. Shabina Ahamad and Dr. John Olyarchuk for their advice.

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