A Clinical Rules Taxonomy for the Implementation of a Computerized Physician Order Entry (CPOE) System

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Many of the benefits of computerized physician order entry (CPOE) stem from its ability to support medical decision-making and error-reduction during patient care. This automated "intelligence" is typically represented by a network of rules. We describe a taxonomic representation of clinical decision-support rules in the context of developing and implementing a de novo CPOE and decision-support system. In our experience, this clinical rules taxonomy facilitated our implementation goals in the areas of physician acceptance and approval, rules construction and maintenance, and technical development and testing. This rules taxonomy may eventually be used to establish standards by which CPOE-based decision-support is measured.

INTRODUCTION

Computerized physician order entry (CPOE), by which physicians and other healthcare workers enter clinical orders directly into a computer system, has been successfully developed and implemented by a small but increasing number of institutions. From these sites, there has been a growing body of literature describing the benefits of CPOE in improving the quality, safety and efficiency of medical care in the hospital setting. Some studies have described the ability of CPOE to reduce medication errors and adverse drug events (1), while others have focused on the reduction of medical costs and the average length of hospital stays.(2,3)

Although CPOE is clearly effective in reducing many of the inefficiencies and errors inherent to manual- and paper-based processes, the most significant benefits of CPOE reside in the area of clinical decision-support and alerting. Studies have described the importance of automated decision-support, by which an "intelligent" computer system alerts the physician either directly or indirectly.(4,5) These systems are ideally, but not necessarily, embedded within a physician order entry system.

In the context of clinical decision-support within CPOE, the "smart" functions are typically represented as clinical "rules." For the purpose of this discussion, a rule is defined as a computer algorithm that supports logic-based calculations and processing. For example, if a physician orders penicillin for a patient who is known by the CPOE system to have a severe allergy to penicillin, an alert is displayed to the physician informing him or her of the hazard. A rule or series of rules is typically defined for each algorithm. Therefore, a typical clinical decision-support system (CDSS) can potentially contain thousands of unique rule-based algorithms. Creating and maintaining such a large number of rules within a CPOE and/or CDSS can consume considerable time and resources. This has led to the establishment of a syntactical rule standard (e.g., Arden Syntax) in hopes of being able to share and exchange sets of clinical rules among heterogeneous systems.(6,7)

However, establishing a standard for clinical rule syntax does not address the task of rules identification and classification for development and implementation of a CPOE system. Although studies describe different types of clinical rules and evaluate their utility, we are unaware of any efforts to organize clinical decision-support rules taxonomically. In our experience, a hierarchical organization has proven important in the systematic identification, development, testing, and institutional approval of clinical rules for use within a CPOE-based clinical decision-support system.

METHODS

Cedars-Sinai Medical Center (CSMC), is a 870 bed community-based academic center affiliated with the UCLA School of Medicine, with over 2000 active physicians, including medical staff, faculty, and housestaff. CSMC is implementing a system-wide
clinical information system, which integrates computerized physician order entry (CPOE), with automated patient management and accounting functions. This system, Patient Care Expert (PCX), is currently being implemented, with a time frame of approximately 2 years from requirements to full system implementation.

Because of our need to expeditiously identify and construct a wide-spectrum of rules for CPOE-based clinical decision-support, we constructed a catalog of rules within the clinical domain. Our approach to clinical rule identification was multi-faceted, and consisted of:

- Review of the informatics literature on clinical rules and decision-support features of CPOE systems.
- Discussion with experts in the areas of clinical decision-support.
- Examination of clinical rules from institutions that have implemented clinical decision-support within CPOE.

As an increasing body of clinical rules was aggregated, these clinical rules were conceptualized and organized hierarchically, based on expected benefit, clinical domain, and rule structure and logic.

This taxonomy was used by programmers to create the rules engine within PCX, to solicit proposal of rules from clinical experts, to gain approval of clinical rules by the appropriate governing-body, and to test the rules underlying the CPOE decision-support features.

RESULTS

At the highest level of the hierarchy, we assigned a primary taxonomic category, based on the clinical "benefit". The nomenclature for this highest taxonomic level is primarily derived from a review of informatics literature describing the proven benefits of CPOE and CDSS. Each rule was also assigned a secondary taxonomic category within the hierarchy. The values for this level are based on primary clinical "domain" (i.e., clinical subspecialty or department). Within each clinical domain, we defined rule "classes" which were grouped according to similarities in rule context, structure and logic (Figure 1). As individual rules or rule classes were identified, they were assigned a brief descriptive name, and placed within the structure of the rules taxonomy.

![Figure 1. Clinical Rules Taxonomy for a Computerized Physician Order Entry System](image)
Benefit:
During the early pre-implementation phase, members of the CPOE implementation team educated clinical and non-clinical staff at all levels of the medical center regarding the “benefit” of CPOE-based decision support and its associated rules infrastructure. From the period of 7/01-7/02, over 150 documented presentations or “live” demos of the system were given at various departmental and executive meetings, committees, and conferences targeting administrative, physician and nursing leadership. This concept of “benefit” was focused on communicating the positive impact of CPOE with clinical decision-support on the safety, quality, and efficiency of healthcare delivery.

Domain:
Under the “benefit” classification, the authors assigned clinical decision-support rules to a “domain”. This designation was used to identify and educate groups of leaders or existing committees that would serve as “owners” for the proposal, construction, approval and ongoing maintenance of a number of rules classes. For instance, the Pharmacy and Therapeutics Committee was given domain over the content and approval of the drug-drug and drug-lab rules classes (among others) after assignment by the CSMC Medical Executive Committee in December 2001. Defining the process of proposing and approving new rules within a class is therefore the responsibility of its domain owner.

Class:
The authors used the term “class” to organize common decision-support rules by a common set of triggers, logic and output. The specifications for each class were first defined by domain experts, and subsequently developed using a database table-driven construct. Every rule class underwent a rigorous process of iterative testing and certification for proper functionality. Once testing was completed, submission of rules data from each domain owner was requested and entered into the system.

DISCUSSION
Most “home-grown” computerized physician order entry (CPOE) systems that exist today were developed at institutions that have implemented clinical decision-support features in a step-wise manner over a number of years or even decades. This approach contrasts with the rapid development and implementation strategy that we have selected for the Patient Care Expert (PCX) system at Cedars-Sinai. To meet our abbreviated project timeline of two years, and our goal of full-featured CPOE and clinical decision-support at initial implementation, we needed to establish a methodology to identify and organize a comprehensive catalog of clinical rules. In order to define the spectrum of rules, we combined methods of literature review, expert opinion, and examination of other CPOE systems. However, we immediately realized that the development of a rules taxonomy has a number of secondary advantages.

Medical Staff Acceptance
A major obstacle to realizing the benefits of any technology-based innovation within the hospital setting is physician and staff acceptance. By organizing the rules taxonomically by benefit, we were able to effectively communicate to hospital leadership and medical staff the role of CPOE in process improvement, error-reduction, clinical decision support, and cost reduction.

Rules Approval and Ownership
The process of defining the requirements and building content for clinical decision support within the PCX system necessitates the knowledge and support of each of the individual clinical departments and multidisciplinary working groups. From a project management perspective, taxonomic organization of clinical rules by domain allows proper assignment of "ownership" among corresponding departments and leaders. For example, within the medication domain, we quickly defined those rule classes requiring resources from our pharmacy department. This taxonomy facilitates efficient division of labor in the myriad of implementation and maintenance tasks.

Technical Development and Testing
On the tertiary level, we defined rule classes based on similarities in rule structure and logic. From a technical standpoint, this grouping allowed a modular approach to rule development, and established a common structure and logic for rules within the same class. For instance, by defining a general rule structure and logic object for drug-lab alerting, we were able to easily implement and test this type of alerting rule for any drug and lab combination. This taxonomic designation was vital in tracking milestones in the technical requirements, building and testing phases.

We doubt that our taxonomy prototype represents a comprehensive hierarchy of all potential clinical decision-support rules or classes. Most likely, there will be new rules classes identified either by us or by others for appropriate inclusion into the taxonomy. In fact, it is very likely that this classification scheme
will evolve in content and in structure, as novel decision-support features are developed and implemented in our system and in other existing CPOE systems.

There are also practical advantages of using a clinical rules taxonomy in evaluating CPOE and other clinical decision-support systems, by comparing the rule "classes". Institutions choosing a commercial CPOE system will undoubtedly want to measure and compare the decision-support "classes" of each product. The Leapfrog Group has constructed a tool by which hospitals can evaluate the effectiveness of their CPOE-based decision-support.(11) A clinical rule taxonomy can facilitate both evaluation and comparison, by establishing a standard nomenclature for decision-support features across systems.

We acknowledge that our taxonomy describes embedded clinical decision support within a CPOE system that contains some, but not all, features of a fully integrated electronic medical record. Since the breadth of clinical rules is dependent on the wealth of data contained within the information system, we expect that our rules taxonomy may either exceed or understate the spectrum of rules within existing or future CPOE systems. However, we believe that our taxonomy may be useful to those interested in the design of a CPOE-based decision-support system, or in the evaluation of an existing system for implementation in a specific healthcare environment.

Although it is beyond the scope of this paper to publish a compendium of rules for clinical decision-support, we maintain that the taxonomic organization of clinical rules offers a number of practical advantages. In our implementation efforts, we have identified important uses of this taxonomy in the areas of physician acceptance, rules construction, approval and maintenance, and in technical development and testing. This taxonomy may also prove useful in developing and describing standards by which CPOE-based decision-support is measured.

REFERENCES:


