Comparing Clinical Decision Support Functionality of Commercially-available Electronic Medical Record Systems

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Certificate of Approval

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ABSTRACT

Clinical decision support systems (CDSS) are computer programs that respond to user activity. They assist clinicians and other health professionals in making better decisions. These systems are used to improve the overall quality of health care. They have helped reduce the cost, prevent errors, save time, and give better end results. Clinical decision support systems are efficient in delivering medical data, hence promoting patient safety, but function differently because of the different designs, definitions, rules, software algorithms, and models they are based on. There is no easy way to group these decision support systems into one common workflow or process. There is a growing need to develop a standard which compares the effectiveness of the various clinical decision support systems.

In this project we developed a common standard or format that can be used to measure the commonalities of the functionalities of multiple decision support systems. This was achieved by evaluating the 42 different 'actions' that are common to various CDSS. The functionalities of 10 different decision support systems were compared. A template was created for better analysis of the data gathered on these 42 actions. These actions were divided into four categories: triggers, data elements, interventions, and offered choices. The data collection was done through an interview process. All systems were evaluated in depth for the decision support capabilities they use. The

'Triggers' category consisted of 9 questions, the 'Input data elements' category consisted of 14 questions, the 'Interventions' category consisted of 7 questions and the 'Offered choices' category consisted of 12 questions. So the total number of questions created for all four categories was 42.

The data collected by the interviews was analyzed and the clinical decision support systems were compared. The comparison was done according to categories and it was seen in every category some systems faired worse than others and others faired good. The study shows that within each category there are differences in the functionalities of the systems. Especially System 6 and 7 are fairing worse across all categories. The study though does not yet tell us what this lack of functionalities means.

1.0 Introduction

Electronic medical records with embedded clinical decision support systems (CDSSs) are computer-based systems used by health professionals or clinicians to help them make clinical decisions. These systems are used to help health professionals analyze patient data by making better decisions in terms of diagnosis, prevention, and treatment of health problems and prevent errors, improve quality, reduce costs, and save time. [2] They are an important resource that provides guidelines and helps clinicians in the diagnostic process. [5]. Evidence shows that these systems have been effective in improving the quality of healthcare in integrated delivery systems and academic medical centers, but still need to expand their use outside of these areas. [7]

Clinical decision support systems can be found in many health care disciplines such as: medicine, dentistry, pharmacy, etc, and the CDSSs in these disciplines are made up of many characteristics and types. There are usually four basic components that make up a CDSS: inference engine (IE), knowledge base (KB), working memory, and explanation module as shown in Figure 1 [2].
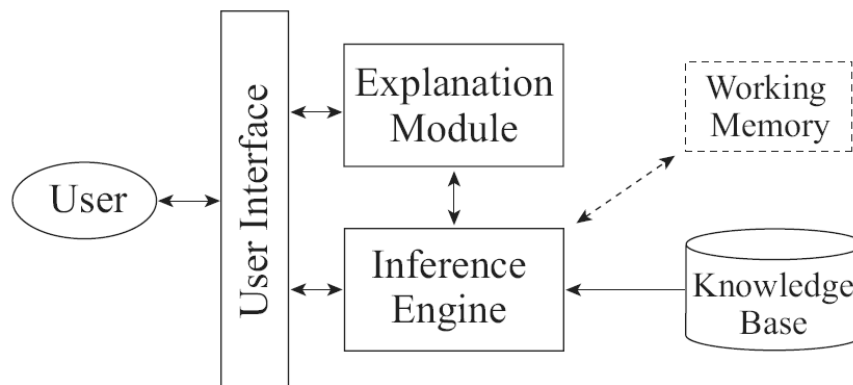

Figure 1: Elements of a typical CDSS. [2]

The inference engine is the main part of the system which deals with the knowledge of the system and the knowledge of the patient data. It basically controls what actions the system needs to take; such as: alerts, reminders, notes, results, diagnosis, etc. The knowledge used by the inference engine is represented in the 'knowledge base' component. The 'working memory' is a collection of patient data that can be stored in a database or in the form of a message. The 'explanation module' is the last component, but does not exist in all CDSSs. The explanation module composes justifications for the results that are derived by the inference engine. These results are gathered from the knowledge base and are compared with the patient data from the working memory component. [2].

There are challenges that occur in developing these systems, along with potential barriers that may occur while using these systems in clinical practice. [2]. Selecting the right architecture for a clinical decision support system is also very important. Studies show that there have been advantages and disadvantages amongst all the architectures that have been selected for these clinical decision support systems [7].

It is very important to know how to correctly evaluate a clinical decision support system. The evaluation process of clinical decision support systems is a key factor in helping figure out how these systems can improve healthcare. Literature reviews indicate that reminders, alerts, treatment plans, and patient education have been effective in changing the behavior of the clinicians [5]. Some studies show that guidelines are

effective, and other studies show that they are not as effective [5]. Studies also show that that there have been a considerable number of times when clinicians do not agree with the standards. Studies also debate whether or not these systems actually help clinicians diagnose problems [5]. Identifying the critical features of a clinical decision support system for improving clinical practice and decisions is very important. Numerous studies and literature have been reviewed and are continuing to be reviewed and analyzed to identify these features. Amongst these studies, randomized controlled trials have been successful in providing results. Findings after reviewing these results show that health professionals should implement clinical decision support systems based on certain functionalities. [3]. In order to make it easier for health professionals to use clinical decision support systems, these functionalities should be implemented: automatic decision support as part of the clinical workflow, deliver decision support at the correct time when decision making needs to take place, provide system guidelines that can be performed, and decision support should be able to be generated by the use of a computer [3]. In general, an effective clinical decision support system is one in which clinicians can retrieve and act on system guidelines in less the effort. [3].

Because of the different designs, definitions, rules, software algorithms, and models of decision support systems, there is no easy way to group these systems into one common workflow or process. There is a growing need to develop a standard which compares the effectiveness of the various clinical decision support systems. This paper is a step towards this goal; various systems are being compared using four sets of features and functions that the systems may or may not have.

2.0 Background

The evaluation of the CDSS will benefit if effort is made to understand how the functional capabilities of a clinical decision support system affect the overall performance of the system.

A functional taxonomy has been created to help in this goal. Taxonomy is 'the science of categorization, or classification, of things based on a predetermined system' [8]. A clinical decision support system's functional taxonomy is the way it organizes its functional features or capabilities into categories and subcategories. [8]. It is important to know which functional capabilities should be a part of a clinical decision support system in order to help make effective clinical decisions. [6] There are many clinical decision support systems that offer all or some of these functional capabilities. Our goal in this paper is to figure out which capabilities are currently present in each system, which are common over all the systems, and which may exist in the future.

Wright et al.'s paper on 'functional taxonomies for clinical decision support systems' shows how different kinds of taxonomies of clinical decision support have been developed by researchers. [6] In this paper, he created a new 'functional' taxonomy based on rule-based clinical decision support. For our research, we have used the functional taxonomy of rule-based clinical decision support created by Wright et al. to inform our data gathering. [6] In creating this taxonomy, Wright created a framework in which he could understand the functional capabilities that must be made available in order to help improve clinical decision making. In this process, he looked at the different approaches

that researchers had already taken in developing different taxonomies. Most of these taxonomies had either been based on expert opinion, or been designed specifically for a task, or had taken an experimental approach. [6]. After evaluation of the taxonomies, he realized that defining the functional capabilities that a clinical decision support system must have is difficult [6]. Wright's goal was to develop his taxonomy of functional capabilities through experimentation. He began his study by defining a specific set of functional capabilities that were small in number, and then reviewed the details of the decision support system which was going to be used to develop his taxonomy. He felt this taxonomy would be useful for decision support systems, developers of clinical systems, and developers of standards. [6].

The system that Wright and other investigators used to form their taxonomy was developed at Partners Healthcare System, which is located in Boston, Massachusetts. Since 2002, Partners' decision support data have been moved into a centralized knowledge management portal. This portal allows room for development and review of clinical knowledge. There were a total of 181 rule types which were reviewed, comprising 7,120 different instances of rule usage. [6] This knowledge management portal covers inpatient and outpatient settings and consists of different types of decision support features such as: medication alerts, reminders, guideline etc. This portal has been improved and made more efficient over the past twenty years. After looking at all the benefits of this knowledge management portal, Wright and other investigators felt that it would be a good area to gather their data from to develop their functional taxonomy. [6].

After conducting a review of the knowledge management portal, Wright and the other investigators developed a taxonomy that consisted of four functional categories. These four categories were: Triggers, Input data, Interventions, and Offered choices. Triggers are actions invoking the decision support rule, like prescribing a drug, requesting a lab test, or entering a problem. [6] Functional category of Input data is described as data elements which are used by rules to make inferences, like patient demographics and laboratory results. [6] Interventions are the actions a decision support module takes, like showing a guideline, sending message to a clinician. [6] 'Offered choice' gives the end user a list of choices to choose from in making their decision. For example, a physician entering an order for a drug the patient is allergic to might allow the clinician to cancel the new order, choose a safer alternative drug, or override the alert. [6].

In these four functional categories, 42 individual elements (actions) were identified, 181 rule types were analyzed, and 7,120 instances of rule usage were reviewed. These categories described and defined the components of an interface between a clinical decision support system and a clinical information system. The individual elements inside each of the four categories were determined, and each rule in the knowledge management portal was assigned to the right group of individual elements. Lastly, the individual elements were reviewed and modified accordingly. [6]

We reviewed 10 different clinical information systems which are being used at various health care facilities. Interviews were conducted at these healthcare facilities with people who use these systems at their work place. Table 1 gives the list of companies (and Interviewee names) we visited or did a phone interview with. The system names

reviewed have been withheld and the systems are instead named from 1 to 10. Below is a brief description of companies which offer these systems. The information generally consists of the type of company, the product they offer, their size and headquarter information and whether their product is CCHIT certified or not. The Certification Commission for Healthcare Information Technology or CCHIT is a recognized certification body (RCB) for electronic health records and their networks, and an independent, voluntary, private-sector initiative. Their mission statement is accelerating the adoption of health information technology by creating an efficient, credible and sustainable certification program. [9] CCHIT was founded in 2004 with support from three leading industry associations in healthcare information management and technology: the American Health Information Management Association (AHIMA), the Healthcare Information and Management Systems Society (HIMSS) and the National Alliance for Health Information Technology(the Alliance). [10]

The Brigham integrated computing system (BICS) helps computing needs of Brigham and Women's Hospital, Boston and was developed by them in house. [11] This Hospital has been in business for 28 years (1980). It is not traded in NYSE and their CCHIT certified product is LMR which is there outpatient system, BICS which is inpatient system is not CCHIT certified yet. [11]

Cerner Millennium is a healthcare information technology computing platform. Cerner Corporation is publicly traded company. It is a Healthcare IT corporation with more than 7,800 employees in the United States and India. Cerner has more than 6,000 clients worldwide and was founded in 1979. The corporate headquarters is located in

North Kansas City, Missouri. [12] Their EMR product we reviewed was Cerner Millennium, Version 2007 and is a CCHIT Certified Ambulatory EHR product. [13]

Eclipsys is a provider of information solutions to healthcare industry. Eclipsys was founded in 1995 and has employee strength of more than 2,500. Their headquarters are in Atlanta, GA and they are traded on Nasdaq (symbol ECLP). Eclipsys clinical solutions we reviewed are called Sunrise Clinical Manager which involves Orders Reconciliation, and Computerized Physical Order Entry. Their product Sunrise Acute Care, a module of Sunrise Clinical Manager, is CCHIT Certified. [14]

'Epic systems' was founded in Madison, Wisconsin in 1979 and has employee strength of around 3000. It is a privately held, employee owned company. Their EpicCare Ambulatory EHR 2007 is a CCHIT Certified. [15] We talked to employees in Kaiser Permanente about this system. Epic offers an integrated suite of healthcare software using database management system (DBMS) called Chronicles. [16]

IDX Systems Corporation (IDX) was a healthcare software technology company found in 1969 with headquarters at Vermont. IDX was acquired by General Electric as part of GE Healthcare business unit in 2006. It employs more than 46,000 people worldwide and is headquartered in Chalfont St. Giles, Buckinghamshire, United Kingdom. GE health is a publicly traded company (NYSE: GE). [17] GE Centricity Electronic Medical Record is CCHIT certified. [18]

McKesson Corporation is publicly traded (NYSE: MCK) and provides health care systems, medical supplies and pharmaceutical products. It is the largest health care

company in the world. It was founded in New York City and has headquarters in San Francisco and has employee strength of 32,000. [19] We reviewed 2 systems from GE healthcare – Practice Partners and Horizon Expert Orders. McKesson's Practice Partner software is CCHIT Certified. [20] Also Horizon Expert Orders software is a pre-market conditional CCHIT Certified Inpatient EHR product for 2007.

Medical Information Technology, Inc. (MEDITECH) is a Massachusetts-based software and service company. MEDITECH is a privately owned company headquartered at Westwood, Massachusetts. The company was a primary contributor to the MUMPS programming language. The company domestically develops, implements and services software products [21] MEDITECH's product Advanced Clinical Systems is CCHIT Certified. [22]

NextGen Healthcare is a provider of integrated electronic medical record and practice management systems. NextGen EMR is CCHIT Certified. NextGen Healthcare is a wholly owned subsidiary of Quality Systems, Inc. (NASDAQ: QSII), headquartered in Horsham, Pennsylvania. [23]

Partners Community Healthcare, Inc. (PCHI) was established in 1994. Partners Healthcare is a non profit organization and owns several Hospitals in Massachusetts. Partners HealthCare's internally developed ambulatory electronic health record (LMR) has been certified by the Certification Commission for Healthcare Information Technology (CCHIT). [24]

3.0 Methods

For our project, we have attempted to develop a common standard or format that can be used to measure the commonalities between the functionalities of multiple decision support systems. We identified different actions or functionalities that were common to different clinical decision support systems by turning Wright's taxonomy paper into a questionnaire. The questionnaire is presented in the 'results' section.

The data collection for this questionnaire has been done through an interview process. Interviews were taken by talking to people from different sites (companies) using various clinical systems. These interviews were conducted either in-person or over the phone, and typical duration of an interview was approximately 45-60 minutes. For our study, ten HIT vendors (or users of these systems) were contacted for our interviews. These included: BICS, Cerner Millenium, Eclipsys, EpicCare, IDX, McKesson, Meditech, NextGen, Practice Partners, and GE. Table 1 below displays the systems which were reviewed, the name of the companies where the systems are used, and the name of the interviewees.

In creating the questions, it was imperative to understand what the four categories: 'Triggers', 'Input data elements', 'Interventions', and 'Offered choices' in a clinical decision support system meant. The example rules described in Wright's taxonomy paper for each individual element also helped in understanding how these four categories function. After evaluating the categories and their definition, each individual element in each category was turned into a question. These questions were then asked in

the form of an action to find out if the 10 clinical decision support systems we reviewed did or did not support certain functionalities.

Table 1: Vendor Data

System Reviewed	Company Name	Interviewee Name
BICS	Brigham and Women's Hospital	Marilyn D. Paterno, MBI
Cerner Millenium	n/a	James McCormack
Eclipsys	n/a	Melissa Honour, MPH
EpicCare	Kaiser Permanente	Micheal Krall, MD
IDX	PeaceHealth	Brian Churchill, Ph.D.
McKesson	Providence	James Carpenter
MediTech	Faulkner Hospital	Dolores Pratt and Sandi Rosenfeld
NextGen	n/a	Sarah Corley, MD
Practice Partners	n/a	Eric Rose, MD
GE	Partners Community Healthcare, Inc. (PCHI)	Nicole Vassar

All the categories were made up of a different number of questions. The 'Triggers' category consisted of 9 questions, the 'Input data elements' category consisted of 14 questions, the 'Interventions' category consisted of 7 questions and the 'Offered choices' category consisted of 12 questions. So the total number of questions created for all four categories was 42. These 42 questions were then put into a Microsoft Excel spreadsheet, and were split up into four different categories: Triggers, Input data, Interventions, and Offered choices. Each category was made up of one table, and then this spreadsheet consisted of four different tables with a total of 42 questions. The columns for all four tables for all four categories consisted of:

- A question regarding the action to perform.

- A description of the action performed.

- An example rule of the action performed.

- The usage of the action for all 10 different clinical decision support systems (Can these systems perform these specific action? yes or no).

Below is an attempt to describe in detail the functionalities of all the 42 individual actions from each category. This description will be useful if the questionnaire needs to be duplicated. Here are the descriptions:

Triggers:

1. Can you activate CDS logic when an Order is entered?

   Description – A clinical decision support system should be able to initiate or trigger logic when any type of clinical order is entered into the computer by an end-user.

2. Can you activate CDS logic when a Laboratory result is stored?

   Description – A clinical decision support system should be able to initiate or trigger logic when any type of clinical laboratory result is stored into the computer by an end-user.

3. Can you activate CDS logic when an Outpatient encounter is opened?

   Description – A clinical decision support system should be able to initiate or trigger logic when any type of clinical outpatient encounter (current patient's medical record) is opened from the computer by an end-user.

4. Can you activate CDS when requested by the User?

   Description – A clinical decision support system should be able to initiate or trigger any type of logic when an end-user is requesting some kind of functionality or data from the computer.

5. Can you activate CDS logic based on a specific time or relative time?

   Description – A clinical decision support system should be able to initiate or trigger logic for the time that multiple tasks occur and the passage of time displayed between tasks by an end-user.

6. Can you activate CDS logic when a patient is admitted to the hospital (Admission order)?

   Description – A clinical decision support system should be able to initiate or trigger logic when any type of patient data entered at the time of admission is entered into the computer by an end-user.

7. Can you activate CDS logic when a new Problem is added to the problem list?

   Description - A clinical decision support system should be able to initiate or trigger logic when any new patient problem description is added to the problem list and entered into the computer by an end-user.

8. Can you activate CDS logic when the user enters a new allergy?

   Description – A clinical decision support system should be able to initiate or trigger logic when any type of patient allergy is entered into the computer by an end-user.

9. Can you activate CDS logic when the user enters a patient's weight?

Description - A clinical decision support system should be able to initiate or trigger logic when a patient's weight is entered into the computer by an end-user.

Input Data:

1. In your CIS can you use a Laboratory result/observation in the CDS logic?

   Description – A clinical decision support system should be able to accept the use of standard laboratory results and structured observations of patients entered into the computer by an end-user as input data to help make inferences.

2. In your CIS can you use a Medication the patient is taking in the CDS logic?

   Description – A clinical decision support system should be able to accept a list of drug descriptions and drug availability for patients entered into the computer by an end-user as input data to help make inferences.

3. In your CIS can you use the Hospital Unit the patient is on in the CDS logic?

   Description – A clinical decision support system should be able to accept a description entered into the computer by an end-user on what hospital unit a patient is being admitted too as input data to help make inferences.

4. In your CIS can you use the patient's Diagnosis/problem in the CDS logic?

   Description - A clinical decision support system should be able to accept a patient's diagnosis/problem list entered into the computer by an end-user as input data to help make inferences.

5. In your CIS can you use the patient's age in the CDS logic?

Description - A clinical decision support system should be able to accept a patient's age entered into the computer by an end-user as input data to help make inferences.

6. In your CIS can you use the patient's Nondrug orders (i.e., nursing, Respiratory therapy, nutrition, etc.) in the CDS logic?

   Description - A clinical decision support system should be able to accept a patient's non-drug orders entered into the computer by an end-user as input data to help make inferences.

7. In your CIS can you use the patient's gender in the CDS logic?

   Description - A clinical decision support system should be able to accept a patient's gender entered into the computer by an end-user as input data to help make inferences.

8. In your CIS can you use the patient's Family history in the CDS logic?

   Description - A clinical decision support system should be able to accept a patient's family history entered into the computer by an end-user as input data to help make inferences.

9. In your CIS can you use the patient's Allergies in the CDS logic?

   Description – A clinical decision support system should be able to accept a patient's allergies entered into the computer by an end-user as input data to help make inferences.

10. In your CIS can you use the patient's weight in the CDS logic?

Description - A clinical decision support system should be able to accept a patient's weight entered into the computer by an end-user as input data to help make inferences.

11. In your CIS can you use the patient's surgical history in the CDS logic?

Describe - A clinical decision support system should be able to accept a patient's surgical history entered into the computer by an end-user as input data to help make inferences.

12. In your CIS can you use the patient's reason for admission in the CDS logic?

Description - A clinical decision support system should be able to accept a patient's reason for admission entered into the computer by an end-user as input data to help make inferences.

13. In your CIS can you use the patient's prior visit types in the CDS logic?

Description - A clinical decision support system should be able to accept a patient's prior visit types entered into the computer by an end-user as input data to help make inferences.

14. In your CIS can you use the patient's race in the CDS logic?

Description - A clinical decision support system should be able to accept a patient's race entered into the computer by an end-user as input data to help make inferences.

Interventions:

1. Can you Notify the user as a result of a CDS rule?

Description – A clinical decision support system should be able to execute a notification (a way of communicating a piece of information) given to an end-user as a result of a CDS rule.

2. Can you log (or store) the results of running a CDS rule for later review?

   Description – A clinical decision support systems should be able to execute logged (or stored) results from running a CDS rule by an end-user for later review.

3. Does your CIS Provide default values (e.g., medication doses) or pick lists based on patient-specific calculations?

   Description – A clinical decision support system should be able to provide default values (e.g., medication doses) or pick lists based on patient-specific calculations entered into the computer by an end-user.

4. Can your CIS show patient- or condition-specific guidelines based on the entry of specific items?

   Description – A clinical decision support system should be able to execute patient-or condition-specific guidelines based on the entry of specific items entered into the computer by an end-user.

5. Can your CIS Collect free text following an entry of a specific type of information?

   Description – A clinical decision support system should be able to collect free text following an entry of a specific type of information into the computer by an end-user.

6. Can your system request approval from a specific department before activating a particular order?

   Description – A clinical decision support system should be able to request approval for a certain action to take place from a specific department by an end-user before activating a particular order.

7. Can your CIS present the user with a data entry template following a specific action (enter order, or new problem)?

   Description – A clinical decision support system should be able to present a data entry template for an end-user following a specific action (enter order or new problem) to take place.

Offered Choices:

1. Can the user Enter an order that was created by the CDS logic directly from the notification screen

   Description – A clinical decision support system should allow the end-user to be able to enter an order (depending upon specific data and requirements) into the computer that is created directly from the notification screen by the CDS logic.

2. Can the user Defer the warning generated by the CDS logic from the notification screen?

   Description - A clinical decision support system should allow the end-user to be able to defer the warning generated by the CDS logic from the notification screen on the computer.

3. Can the user Override a rule and keep the current order from the notification screen?

   Description – A clinical decision support system should allow the end-user to be able to override a rule executed by the computer and keep the current order from the notification screen on the computer.

4. Can the user Cancel an existing order from the notification screen?

   Description – A clinical decision support system should give the end-user a choice of canceling an already existing order from the notification screen after a potential order has been entered into the computer.

5. Can the user Cancel the newly entered order from the notification screen?

   Description – A clinical decision support system should give the end-user a choice of canceling the newly entered order from the notification screen after a potential order has been entered into the computer.

6. Can the user Edit or modify the newly created order from the notification screen?

   Description - A clinical decision support system should give the end-user a choice of editing or modifying the newly created order from the notification screen after a potential order has been entered into the computer.

7. Can the user Edit an existing order directly from the notification screen?

   Description - A clinical decision support system should give the end-user a choice of editing an existing order directly from the notification screen after a potential order has been entered into the computer.

8. Can the user enter or change an allergy directly from the notification screen?

Description – A clinical decision support system should give the end-user a choice of entering or changing an allergy directly from the notification screen on the computer.

9. Can the system generate a patient-specific letter based on CDS logic?

Description – A clinical decision support system should give the end-user a choice to be able to generate a patient-specific letter based on CDS logic.

10. Can the system generate a clinical note based on CDS logic?

Description - A clinical decision support system should give the end-user a choice to be able to generate a clinical note based on CDS logic.

11. Can the system modify the patient's problem list based on CDS logic?

Description - A clinical decision support system should give the end-user a choice to be able to modify the patient's problem list based on CDS logic.

12. Can the system prompt the user to enter the patient's weight, height, or age when needed for a specific CDS calculation?

Description – A clinical decision support system should give the end-user a choice of either entering the patient's weight, height, or age when needed for a specific CDS calculation.

The interview was conducted with 10 interviewees, who are users of one CDSS each. In all 10 CDSS were evaluated, resulting in data on 10 interviews with 42 Questions each. It was made sure that the interviewee was either familiar with or worked with one of the 10 clinical decision support systems we reviewed. Based on their answers, either a 'YES', 'NO' or 'N/A' was entered into the correct column, and comments were entered

where necessary. Data from the 10 systems we reviewed is shown below in the 'Results' section.

4.0 Results

The results of the interview is tabulated in an excel sheet format. The four categories of questions which were asked in the interview to the 10 different interviewees are displayed below (Table 2a to 2d). Each table consists of 12 columns. The first column displays the question asked, and the second column gives an example. Rest of the 10 columns contains the data from the interview. The data is in Yes / No or N/A format as all the questions were designed towards a binary answer, though some questions were not applicable (N/A) for the system being reviewed.

Table 2a: Category 1 - Triggers for Decision Support

Question regarding Action	Example Rule	System									
		1	2	3	4	5	6	7	8	9	10
1. Can you activate CDS logic when an Order is entered?	When digoxin is ordered, check potassium.	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
2. Can you activate CDS logic when a Laboratory result is stored?	When glucose is stored, check value.	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES
3. Can you activate CDS logic when an Outpatient encounter is opened?	When a patient presents for a routine physical, order cholesterol test if needed.	N/A	YES	YES	YES	YES	N/A	YES	YES	YES	YES
4. Can you activate CDS logic when requested by the User	When user requests them, show antibiotic utilization guidelines.	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
5. Can you activate CDS logic based on a specific time or relative time?	24 hours after admission, check for a medication list.	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
6. Can you activate CDS logic when a patient is admitted to the hospital (Admission order)?	When a patient is admitted for congestive heart failure, offer standard therapy.	YES	YES	YES	N/A	YES	NO	YES	N/A	N/A	N/A
7. Can you activate CDS logic when a new Problem is added to the problem list?	When asthma is diagnosed, request date of onset.	YES	YES	YES	YES	YES	NO	NO	YES	YES	YES
8. Can you activate CDS logic when the user enters a new allergy?	When a penicillin allergy is entered, check drug list	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES
9. Can you active CDS logic when the user enters a patient's weight?	When a patient's weight is entered, ensure that it is reasonable.	NO	YES	YES	YES	YES	NO	NO	YES	YES	YES

Table 2b: Category 2 - Input Data Elements Consumed by Decision Support Rules

Question regarding Action	Example Rule	System									
		1	2	3	4	5	6	7	8	9	10
1. In your CIS can you use a Laboratory result/observation in the CDS logic	Check if latest hemoglobin A1C > 6%.	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
2. In your CIS can you use a Medication the patient is taking in the CDS logic	Active prescription for fluoxetine.	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
3. In your CIS can you use the Hospital Unit the patient is on in the CDS logic	Coronary care unit.	YES	YES	YES	N/A	YES	YES	YES	N/A	N/A	N/A
4. In your CIS can you use the patient's Diagnosis/problem in the CDS logic?	Decrease dose of cefuroxime in patients with renal insufficiency.	YES	YES	YES	YES	YES	NO	NO	YES	YES	YES
5. In your CIS can you use the patient's age in the CDS logic?	Warn about nifedipine use in the elderly.	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
6. In your CIS can you use the patient's Nondrug orders (i.e., nursing, Respiratory therapy, nutrition, etc.) in the CDS logic?	Patient has an active total parenteral nutrition order.	YES	YES	YES	YES	YES	YES	YES	YES	NO	N/A
7. In your CIS can you use the patient's gender in the CDS logic?	Only suggest a mammogram in female patients.	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
8. In your CIS can you use the patient's Family history in the CDS logic?	Suggest lipid panel more frequently for patients with family history of myocardial infarction.	NO	YES	YES	YES	YES	NO	NO	YES	YES	YES
9. In your CIS can you use the patient's Allergies in the CDS logic?	Check for a penicillin allergy when amoxicillin is prescribed.	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
10. In your CIS can you use the patient's weight in the CDS logic?	Suggest lipid panel more frequently for overweight patients.	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
11. In your CIS can you use the patient's surgical history in the CDS logic?	Do not recommend mammogram with history of bilateral mastectomy.	YES	YES	YES	YES	YES	NO	NO	YES	YES	YES
12. In your CIS can you use the patient's reason for admission in the CDS logic?	Suggest default orders when a patient is admitted for myocardial infarction.	YES	YES	YES	YES	YES	NO	NO	YES	N/A	N/A
13. In your CIS can you use the patient's prior visit types in the CDS logic?	Check for ophthalmology visit in the past year for diabetic patients.	YES	YES	YES	YES	YES	N/A	NO	YES	YES	YES
14. In your CIS can you use the patient's race in the CDS logic?	Recommend a calcium channel blocker for patients with black race.	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES

Table 2c: Category 3 - Interventions by Decision Support Systems

Question regarding Action	Example Rule	System									
		1	2	3	4	5	6	7	8	9	10
1. Can you Notify the user as a result of a CDS rule?	Alert the user when a patient's potassium is > 5.	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
2. Can you log (or store) the results of running a CDS rule for later review?	Log all uses of ketorolac for utilization review.	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES
3. Does your CIS Provide default values (e.g., medication doses) or pick lists based on patient-specific calculations?	Compute recommended doses for a patient with renal impairment.	YES	YES	YES	YES	YES	YES	NO	YES	YES	YES
4. Can your CIS show patient- or condition-specific guidelines based on the entry of specific items?	Show guidelines for use of antibiotics.	YES	YES	YES	YES	YES	NO	NO	YES	YES	YES
5. Can your CIS Collect free text following an entry of a specific type of information?	Request a reason for overriding an alert.	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
6. Can your system request approval from a specific department before activating a particular order?	Send order to endocrinology when growth hormone is ordered.	YES	YES	YES	YES	YES	NO	NO	YES	NO	YES
7. Can your CIS present the user with a data entry template following a specific action (enter order, or new problem)?	Request details when asthma is added as a problem.	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

Table 2d: Category 4 - Offered Choices as Part of Notification Interventions

Question regarding Action	Example Rule	System 1	2	3	4	5	6	7	8	9	10
1. Can the user Enter an order that was created by the CDS logic directly from the notification screen?	Change a ranitidine order to famotidine.	YES	YES	YES	YES	YES	YES	NO	YES	NO	YES
2. Can the user Defer the warning generated by the CDS logic from the notification screen?	Allow the user to defer a warning for 24 hours.	YES	NO	NO	YES	NO	NO	NO	NO	NO	YES
3. Can the user Override rule and keep the current order from the notification screen?	Keep an order that triggered a low-severity drug interaction rule.	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
4. Can the user Cancel an existing order from notification screen?	Discontinue an existing order for fluoxetine when it is flagged as duplicating a new order for paclitaxel.	YES	YES	YES	YES	YES	NO	NO	NO	NO	YES
5. Can the user Cancel the newly entered order from the notification screen?	Cancel an order for furosemide in a patient with a sulfa drug allergy.	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
6. Can the user Edit or modify the newly created order from the notification screen?	Change the dose of an order for 16 g acetaminophen.	YES	NO	YES	NO	YES	YES	NO	YES	YES	YES
7. Can the user Edit an existing order directly from the notification screen?	Reduce digoxin when patient is hyponatremic.	YES	NO	YES	NO	NO	NO	NO	NO	NO	YES
8. Can the user enter or change an allergy directly from the notification screen?	Decline a suggestion to order atenolol because the patient is allergic.	NO	NO	NO	YES	NO	YES	NO	NO	NO	YES
9. Can the system generate a patient-specific letter based on CDS logic?	Send a letter to a patient with a normal mammogram.	YES	YES	YES	YES	NO	NO	YES	YES	YES	YES
10. Can the system generate a clinical note based on CDS logic?	Provide default text for a note on a patient with an elevated low-density lipoprotein level.	YES	YES	YES	NO	YES	NO	NO	NO	YES	YES
11. Can the system modify the patient's problem list based on CDS logic?	Remove hypertension from the problem list in response to a suggestion for antihypertensive therapy.	NO	YES	NO	YES	YES	NO	NO	NO	YES	YES
12. Can the system prompt the user to enter the patient's weight, height, or age when needed for a specific CDS calculation?	Allow user to enter weight when ordering a drug with weight-based dosing.	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

The four categories are –

Category 1: Triggers for Decision Support

There are 9 Questions in this section. All referring to whether or not the functionality can be activated in the system in question. The data shows that the system 6 has the least trigger functionalities with 4 questions answered – NO. All other systems are comparable. System 2 and System 3 fair the best in this category with all answers 'YES'.

Category 2: Input Data Elements Consumed by Decision Support Rules

There are 14 Questions in this section. The questions are regarding CIS usability of the system in question. The data shows that both system 6 and system 7 score low in this category with 5 NO answers each. System 2 and System 3 and System 5 fair the best in this category with all answers 'YES'.

Category 3: Interventions by Decision Support Systems

There are 7 Questions in this section regarding Interventions in CDSS in question. The data shows that system 7 scores low in this category with 3 NO answers followed by system 9 and 6 with 2 NO answers. All systems fair very well in this category. System 1, System 2, System 3, System 4, System 5, System 8 and System 10 fair the best in this category with all answers 'YES'.

Category 4: Offered Choices as Part of Notification Interventions

There are 12 Questions on this section regarding offered choices for the user. Only one system had all the functionality listed in this section. All other systems have a mixed bag of answers with system 7 fairing much worse than the others (I.e., 8 NO answers). Only System 10 fairs the best in this category with all answers 'YES'. All other systems have at least 2 'NO' answers. This category seems to have the most functionality which needs attention from all the systems.

5.0 Discussion

This study was done to compare different CDSS systems on the scale of 42 questions describing all the functionalities of a system. This comparison was done by interviewing users of these systems being used in different environments in various healthcare facilities. The study shows that within each category there are differences in the functionalities of the systems. Especially System 6 and 7 are fairing worse, i.e. they have more 'NO' answers than any of the other systems. The study though does not yet tell us what this lack of functionalities means. How does this affect the performance and how we can quantify it? There is a need to find out further how these systems are fairing in the actual work environment as compared to the best systems as per this study.

The study was done in healthcare facilities predominantly located in Portland and Boston area. It did not represent a geographic widespread representation of the data which though not very important but would be desirable. Also the study was conducted by interviewing users of one system in a facility. It would have been interesting to find

out what answers are given by users of the same systems in other facilities. Right now in this study we have only one set of data per system, but it would be desirable to see what kind of repeatability we find if we take the same set of data for the same systems being used in other environments.

6.0 Conclusion

The data collected by the interviews has been analyzed and the clinical decision support systems have been compared. Calculating the total number of common actions and their common functionalities amongst these 10 systems has given a better idea on how to create a common standard amongst clinical decision support systems in the healthcare environment. System 6 and 7 fair worse than other systems in all the categories which were created for this study.

I am grateful to Dr Sittig for giving me a chance to work on this project and for his guidance for successful completion of this study. I am grateful to Adam for sharing his knowledge on this study and helping me with the concepts and background details. A big thanks to all the interviewees who took out there time to answer the questions in the study on the systems; Marilyn D. Paterno, James McCormack, Melissa Honour, Micheal Krall, Brian Churchill, James Carpenter, Dolores Pratt, Sandi Rosenfeld, Sarah Corley, Eric Rose, and Nicole Vassar.

Appendix A
Blank Sheet of Questions Asked for Interviews -

Table 3a: Category 1 - Triggers for Decision Support

Question regarding Action	Example Rule	System									
		1	2	3	4	5	6	7	8	9	10
1. Can you activate CDS logic when an Order is entered?	When digoxin is ordered, check potassium.										
2. Can you activate CDS logic when a Laboratory result is stored?	When glucose is stored, check value.										
3. Can you activate CDS logic when an Outpatient encounter is opened?	When a patient presents for a routine physical, order cholesterol test if needed.										
4. Can you activate CDS logic when requested by the User	When user requests them, show antibiotic utilization guidelines.										
5. Can you activate CDS logic based on a specific time or relative time?	24 hours after admission, check for a medication list.										
6. Can you activate CDS logic when a patient is admitted to the hospital (Admission order)?	When a patient is admitted for congestive heart failure, offer standard therapy.										
7. Can you activate CDS logic when a new Problem is added to the problem list?	When asthma is diagnosed, request date of onset.										
8. Can you activate CDS logic when the user enters a new allergy?	When a penicillin allergy is entered, check drug list										
9. Can you active CDS logic when the user enters a patient's weight?	When a patient's weight is entered, ensure that it is reasonable.										

Table 3b: Category 2 - Input Data Elements Consumed by Decision Support Rules

Question regarding Action	Example Rule	System									
		1	2	3	4	5	6	7	8	9	10
1. In your CIS can you use a Laboratory result/observation in the CDS logic	Check if latest hemoglobin A1C > 6%.										
2. In your CIS can you use a Medication the patient is taking in the CDS logic	Active prescription for fluoxetine.										
3. In your CIS can you use the Hospital Unit the patient is on in the CDS logic	Coronary care unit.										
4. In your CIS can you use the patient's Diagnosis/problem in the CDS logic?	Decrease dose of cefuroxime in patients with renal insufficiency.										
5. In your CIS can you use the patient's age in the CDS logic?	Warn about nifedipine use in the elderly.										
6. In your CIS can you use the patient's Nondrug orders (i.e., nursing, Respiratory therapy, nutrition, etc.) in the CDS logic?	Patient has an active total parenteral nutrition order.										
7. In your CIS can you use the patient's gender in the CDS logic?	Only suggest a mammogram in female patients.										
8. In your CIS can you use the patient's Family history in the CDS logic?	Suggest lipid panel more frequently for patients with family history of myocardial infarction.										
9. In your CIS can you use the patient's Allergies in the CDS logic?	Check for a penicillin allergy when amoxicillin is prescribed.										
10. In your CIS can you use the patient's weight in the CDS logic?	Suggest lipid panel more frequently for overweight patients.										
11. In your CIS can you use the patient's surgical history in the CDS logic?	Do not recommend mammogram with history of bilateral mastectomy.										
12. In your CIS can you use the patient's reason for admission in the CDS logic?	Suggest default orders when a patient is admitted for myocardial infarction.										
13. In your CIS can you use the patient's prior visit types in the CDS logic?	Check for ophthalmology visit in the past year for diabetic patients.										
14. In your CIS can you use the patient's race in the CDS logic?	Recommend a calcium channel blocker for patients with black race.										

Table 3c: Category 3 - Interventions by Decision Support Systems

Question regarding Action	Example Rule	System 1	2	3	4	5	6	7	8	9	10
1. Can you Notify the user as a result of a CDS rule?	Alert the user when a patient's potassium is > 5.										
2. Can you log (or store) the results of running a CDS rule for later review?	Log all uses of ketorolac for utilization review.										
3. Does your CIS Provide default values (e.g., medication doses) or pick lists based on patient-specific calculations?	Compute recommended doses for a patient with renal impairment.										
4. Can your CIS show patient- or condition-specific guidelines based on the entry of specific items?	Show guidelines for use of antibiotics.										
5. Can your CIS Collect free text following an entry of a specific type of information?	Request a reason for overriding an alert.										
6. Can your system request approval from a specific department before activating a particular order?	Send order to endocrinology when growth hormone is ordered.										
7. Can your CIS present the user with a data entry template following a specific action (enter order, or new problem)?	Request details when asthma is added as a problem.										

Table 3d: Category 4 - Offered Choices as Part of Notification Interventions

Question regarding Action	Example Rule	System 1	2	3	4	5	6	7	8	9	10
1. Can the user Enter an order that was created by the CDS logic directly from the notification screen?	Change a ranitidine order to famotidine.										
2. Can the user Defer the warning generated by the CDS logic from the notification screen?	Allow the user to defer a warning for 24 hours.										
3. Can the user Override rule and keep the current order from the notification screen?	Keep an order that triggered a low-severity drug interaction rule.										
4. Can the user Cancel an existing order from notification screen?	Discontinue an existing order for fluoxetine when it is flagged as duplicating a new order for paclitaxel.										
5. Can the user Cancel the newly entered order from the notification screen?	Cancel an order for furosemide in a patient with a sulfa drug allergy.										
6. Can the user Edit or modify the newly created order from the notification screen?	Change the dose of an order for 16 g acetaminophen.										
7. Can the user Edit an existing order directly from the notification screen?	Reduce digoxin when patient is hyponatremic.										
8. Can the user enter or change an allergy directly from the notification screen?	Decline a suggestion to order atenolol because the patient is allergic.										
9. Can the system generate a patient-specific letter based on CDS logic?	Send a letter to a patient with a normal mammogram.										
10. Can the system generate a clinical note based on CDS logic?	Provide default text for a note on a patient with an elevated low-density lipoprotein level.										
11. Can the system modify the patient's problem list based on CDS logic?	Remove hypertension from the problem list in response to a suggestion for antihypertensive therapy.										
12. Can the system prompt the user to enter the patient's weight, height, or age when needed for a specific CDS calculation?	Allow user to enter weight when ordering a drug with weight-based dosing.										

7.0 References

[1]   Kuilboer MM, van Wijk MAM, Mosseveld M, van der Does E, Ponsioen BP, de Jongste JC, overbeek SE and van der lei J. 'Feasibility of AsthmaCritic, a decision-support system for asthma and COPD which generates system-specific feedback on routinely recorded data in general practice.' Family Practice 2002; 19: 442-447.

[2]   Eneida A. Mendonça, M.D., 'Clinical Decision Support Systems: Perspectives in Dentistry', Journal of Dental Education, 589.

[3]   Kensaku Kawamoto, Caitlin A Houlihan, E Andrew Balas and David F Lobach, 'improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success**.'** *BMJ* 2005;330;765 BMJ, doi:10.1136/bmj.38398.500764.8F (published 14 March 2005).

[4]   Dereck L. Hunt, MD; R. Brian Haynes, MD, PhD; Steven E. Hanna, MA, PhD; Kristina Smith, 'Effects of Computer-Based Clinical Decision Support Systems on Physician Performance and Patient Outcomes A Systematic Review' JAMA, October 21, 1998—Vol 280, No. 15.

[5]   Kaplan B, 'Evaluating informatics applications—clinical decision support Systems literature review' International Journal of Medical Informatics 64 (2001) 15–37.

[6]   Wright A, Goldberg H, Hongsermeier T, Middleton B, 'A Description and Functional Taxonomy of Rule-based Decision Support Content at a Large

Integrated Delivery Network', Journal of the American Medical Informatics Association Volume 14 Number 4 July / August 2007.

[7]   Wright A, Sittig DF, 'A framework and model for evaluating clinical decision support architectures', J Biomed Inform (2008), doi:10.1016/j.jbi.2008.03.009

[8]   http://isp.webopedia.com/TERM/T/taxonomy.html

[9]   http://www.cchit.org/

[10]   http://en.wikipedia.org/wiki/CCHIT

[11]   Int J Med Inform. 1999 Jun; 54(3):197-208. The Brigham integrated computing system (BICS): advanced clinical systems in an academic hospital environment. Teich JM, Glaser JP, Beckley RF, Aranow M, Bates DW, Kuperman GJ, Ward ME, Spurr CD.

[12]   http://en.wikipedia.org/wiki/Cerner

[13]   http://www.cchit.org/choose/ambulatory/2007/Cerner-Millennium-PowerChart-PowerWorks-EMR.asp

[14]   http://www.eclipsys.com/

[15]   http://www.epicsystems.com/

[16]   http://en.wikipedia.org/wiki/Epic_Systems_Corporation

[17]   http://en.wikipedia.org/wiki/IDX_Systems

[18]   http://www.gehealthcare.com/usen/cis/products/groupcast/emr_install.html

[19]   http://en.wikipedia.org/wiki/McKesson

[20]   http://www.cchit.org/choose/ambulatory/2007/McKesson-Provider-Technologies-Practice-Partner-9.2.2.asp

[21]   http://en.wikipedia.org/wiki/Meditech

[22]   http://www.meditech.com/aboutmeditech/pages/newsmeditechcchitcertcs.htm

[23]   http://www.nextgen.com/

[24]   http://www.partners.org/about/about_pchi.html