Clinician Decision Support (CDS) Dashboard: Extracting value from Electronic Medical Records

ICCHA SETHI

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Master of Science in Computer Science

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ABSTRACT

Medical records are rapidly being digitized to electronic medical records. Although Electronic Medical Records (EMRs) improve administration, billing, and logistics, an open research problem remains as to how doctors can leverage EMRs to enhance patient care. This thesis describes a system that analyzes a patient’s evolving EMR in context with available biomedical knowledge and the accumulated experience recorded in various text sources including the EMRs of other patients. The aim of the Clinician Decision Support (CDS) Dashboard is to provide interactive, automated, actionable EMR text-mining tools that help improve both the patient and clinical care staff experience. The CDS Dashboard, in a secure network, helps physicians find de-identified electronic medical records similar to their patient's medical record thereby aiding them in diagnosis, treatment, prognosis and outcomes. It is of particular value in cases involving complex disorders, and also allows physicians to explore relevant medical literature, recent research findings, clinical trials and medical cases. A pilot study done with medical students at the Virginia Tech Carilion School of Medicine and Research Institute (VTC) showed that 89% of them found the CDS Dashboard to be useful in aiding patient care for doctors and 81% of them found it useful for aiding medical students pedagogically. Additionally, over 81% of the medical students found the tool user friendly. The CDS Dashboard is constructed using a multidisciplinary approach including: computer science, medicine, biomedical research, and human-machine interfacing. Our multidisciplinary approach combined with the high usability scores obtained from VTC indicated the CDS Dashboard has a high potential value to clinicians and medical students.
ACKNOWLEDGMENTS

My advisor and mentor, Dr. Harold ‘Skip’ Garner, has been a source of inspiration for me during the past two years. I thank him foremost for his continual support, guidance, and the wisdom he has shared with me. I have learned a lot from him not only pertaining to research but also about many aspects of life.

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<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMR</td>
<td>Electronic Medical Record</td>
</tr>
<tr>
<td>EHR</td>
<td>Electronic Health Record</td>
</tr>
<tr>
<td>OECD</td>
<td>Organization for Economic Cooperation and Development</td>
</tr>
<tr>
<td>IOM</td>
<td>Institute of Medicine</td>
</tr>
<tr>
<td>CBPRS</td>
<td>Computer Based Patient Record System</td>
</tr>
<tr>
<td>EM</td>
<td>Emergency Medicine</td>
</tr>
<tr>
<td>CPR</td>
<td>Computerized Patient Record</td>
</tr>
<tr>
<td>HIT</td>
<td>Health and Information Technology</td>
</tr>
<tr>
<td>CDSS</td>
<td>Clinical Decision Support System</td>
</tr>
<tr>
<td>ADEL</td>
<td>Acid-Base and Electrolyte program</td>
</tr>
<tr>
<td>QMR</td>
<td>Quick Medical Reference</td>
</tr>
<tr>
<td>PHP</td>
<td>Hypertext Preprocessor</td>
</tr>
<tr>
<td>JSON</td>
<td>JavaScript Object Notation</td>
</tr>
<tr>
<td>JQuery</td>
<td>JavaScript Query</td>
</tr>
</tbody>
</table>
CHAPTER 1: INTRODUCTION

The era of “information revolution” might have started decades ago with the invention of the integrated chip, but its ramifications are still growing multifold every single day. This growth of information technology has not only affected the personal lives of many - changing the way people communicate all over the globe using computers and cellular phones, the way they spend their time, the kind of work they do and many other aspects of their lives; but has also revolutionized many industries. During the 1990s, many industries like telecommunications and general merchandising invested heavily in information technology (IT) and reaped enormous benefits including 6-8 percent annual productivity growth. In the recent years, the health care industry has been making similar efforts of adopting information technology to increase productivity gains [Hillstead et al. 2005].

The U.S. health care industry is one of the world’s largest industries. It absorbs more than $1.7 trillion per year, which is twice the amount recommended by the Organization for Economic Cooperation and Development (OECD) and yet the premature mortality rate in the U.S. is much higher than the average [Health at a Glance, 2011]. The amalgamation of information technology with health care can be done in many ways, one of the most important ways being the conversion to electronic medical records (EMRs). It is widely believed that the adoption of electronic medical records on a large scale can not only help improve health and reduce medical errors, but also increase the health care savings and revenue. Computer science and technology can help take the benefits of EMRs one step further by providing doctors with systems which not only record the patient details, but also help analyze them and provide decision support.

1.1 Electronic Medical Record

The electronic medical record is formally defined as a computerized medical record created in an organization that delivers care, such as a hospital or physician's office [Evans JA 1999]. The following subsections describe how paper medical records evolved into electronic medical records, the advantages of electronic medical records, and the barriers and challenges in acceptance of EMRs.

1.1.1 Evolution of Electronic Medical Records

The traditional paper based medical record arose around the early 19th century as a highly personalized ‘lab notebook’ which was used by the physicians to record important details about patients which they could look up the next time the patient visited. There was no formal structure to it and no assumption that it would need to be shared with other health service providers. It was not bound by any administrative requirements or formal standards. This paper based medical record system which evolved to meet the needs of physicians a century ago, has been struggling to keep up with the modern day advancements in health care.

The concept of electronic medical records has been around since 1972 when it was introduced by the Regenstrief Institute [Murray MD, et al. 2003]. In early 1992, a committee was formed by the Institute of Medicine (IOM) to address several issues like the need for better health care services,
lack of sufficient health data, and cost effective care providers. The study committee consisted of a wide array of individuals from administrators in health organizations and non-health organizations, medical practitioners, representatives from health insurance, consumers, data security, health and privacy laws, ethics, informatics and state health data organizations. Based on the study conducted by the committee several recommendations were made including the suggestion of computer based patient records [R.S. Dick et al. 1997].

### 1.1.2 Advantages of Electronic Medical Records

There have been several papers discussing the advantages and disadvantages of electronic medical records. One of the earlier papers in 1994 says that a user friendly, stable and consistent computer based patient record system helps improve the quality of healthcare [Sittig DF et al. 1994]. A survey of the Emergency Medicine (EM) physicians and nurses at a large urban teaching hospital, after implementation of an Emergency Department EMR, revealed that the nurses felt that the use of computers reduced their paperwork thus increasing productivity [Likourezos A et al. 2004]. During the same period a literature review of the various papers published on evaluating EMR systems was done [Delpierre C et al. 2004]. This review brought to light that these systems increased physician and patient satisfaction.

Some of the later studies include a survey conducted by David Joos et al. administered in an adult primary care clinic to analyze and identify the features of an EMR system which contributed to user satisfaction [D. Joos et al. 2006]. This study was conducted at an adult ambulatory primary care and urgent care clinic in an academic hospital. The system study included access to all internally generated notes, scans, lab reports and an electronic messaging system incorporated into the EMR. The paper discusses the various advantages of the EMR system uncovered by the survey. Physicians and nurses found that they could find patient records faster and also respond to telephonic queries by patients much quicker. The EMR system also increased the efficiency by reducing the effort required to review a patient’s medical history, communicate with staff or access lab results. One of the major advantages of the system was the ability to access it when away from the clinic.

Work by T.L. Erstad in 2003 categorized the advantages into clinical, workflow, administrative and revenue enhancement [T.L. Erstad 2003]. The paper discusses that Computerized Patient Records (CPR) tools help standardize patient records and minimize errors.

One of the major long term advantages of adopting the electronic medical record system recurring in many publications is the financial savings which has been discussed in the next section.

#### 1.1.2.1 Cost Benefits of EMRs

Using electronic medical record system can help increase revenue at various levels. Using technology ensures effective management of information at point of care and billing office. Most EMR systems are programmed to generate reminders about overdue health maintenance issues thereby increasing the health maintenance visits. Renner cited a study which found that the using computer based systems for patient care reduced the cost from $1539 to $943 in comparison to using paper chart group [Renner K 1996]. Computer based systems also ensured
improved coding. This helps reduce the amount of money lost by inaccurate coding [T.L. Erstad 2003].

Using a simulation model of health and information technology (HIT) and scaling literature based HIT effects Hillstead et al. built a national estimate of the potential savings from adoption information technology in health care. Figure 1 savings estimated for both outpatient and inpatient care at a 90% adoption rate and estimates the average to be more than $77 billion per year. Figure 2 plots the net cumulative and yearly potential savings from EMR systems and outpatient settings over time. The cumulative potential net efficiency and safety savings from hospital systems could be nearly $371 billion [Hillstead et al. 2005].

<table>
<thead>
<tr>
<th>Savings category</th>
<th>Mean yearly savings ($ billions)</th>
<th>Cumulative savings by year 15 ($ billions)</th>
<th>Annual savings ($ billions)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Year 5</td>
<td>Year 10</td>
</tr>
<tr>
<td>Outpatient</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transcription</td>
<td>0.9</td>
<td>13.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Chart pulls</td>
<td>0.8</td>
<td>11.9</td>
<td>0.4</td>
</tr>
<tr>
<td>Lab test</td>
<td>1.1</td>
<td>15.9</td>
<td>0.5</td>
</tr>
<tr>
<td>Drug usage</td>
<td>6.2</td>
<td>92.3</td>
<td>3.0</td>
</tr>
<tr>
<td>Radiology</td>
<td>1.7</td>
<td>25.6</td>
<td>0.8</td>
</tr>
<tr>
<td>Total outpatient savings</td>
<td>10.6</td>
<td>159.0</td>
<td>5.2</td>
</tr>
<tr>
<td>Inpatient</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nursing time</td>
<td>7.1</td>
<td>106.4</td>
<td>3.4</td>
</tr>
<tr>
<td>Lab test</td>
<td>1.6</td>
<td>23.4</td>
<td>0.8</td>
</tr>
<tr>
<td>Drug usage</td>
<td>2.0</td>
<td>29.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Length-of-stay</td>
<td>19.3</td>
<td>289.6</td>
<td>10.1</td>
</tr>
<tr>
<td>Medical records</td>
<td>1.3</td>
<td>19.9</td>
<td>0.7</td>
</tr>
<tr>
<td>Total inpatient savings</td>
<td>31.2</td>
<td>468.5</td>
<td>16.1</td>
</tr>
<tr>
<td>Total</td>
<td>41.8</td>
<td>627.5</td>
<td>21.3</td>
</tr>
</tbody>
</table>

Figure 1. Potential Efficiency Savings With Adoption Of Electronic Medical Record (EMR) Systems [Hillstead et al. 2005] SOURCE: F. Girosi et al., Extrapolating Evidence of Health Information Technology Savings and Costs, Pub. no. MG-410 (Santa Monica, Calif.: RAND, 2005), sec. 4.2.6.

NOTE: These savings have not been discounted, nor do they take into account inflation in health care expenditures.

The potential savings at 100 percent adoption would obviously be larger, but the uncertainty about when and whether that level can be reached is very high. We have assumed a fifteen-year adoption period, based on A. Bower, The Diffusion and Value of Healthcare Information Technology, Pub. no. MG-272-HLTH (Santa Monica, Calif.: RAND, 2005).
Figure 2. Net Potential Savings (Efficiency Benefits Over Adoption Costs) For Hospital And Physician Electronic Medical Record (EMR) Systems Adoption During A Fifteen-Year Adoption Period (2004–2018) [Hillstead et al. 2005]

SOURCE: F. Girosi et al., Extrapolating Evidence of Health Information Technology Savings and Costs (Santa Monica, Calif.: RAND, 2005)

1.1.3 Barriers to Acceptance of EMRs


Figure 3 from the paper shows not only the barriers identified, but also the possible solutions or interventions for the barriers suggested. For example, one of the major hurdles being psychological and the aversion to change. This can be overcome by various strategies including, fellow physicians demonstrating the use of EMR Management system and emphasizing on its ease of use.
1.2 Clinical Decision Support System

A study done by the US Institute of Medicine shows that up to 98,000 US residents die each year as a consequence of preventable medical errors [Kohn LT et al. 1999]. Analogously a study done at two London hospitals revealed that 11% of the admitted patients experienced adverse events of which 48% were preventable and of which 8% led to death [Vincent C et al. 2001].

To address these deficiencies in health care, hospitals are increasingly looking at clinical decision support systems to aide clinicians in patient care. The adoption of electronic medical records provides the necessary skeleton to build these systems by providing the required input in an automated and structured format.
Clinical Decision Support Systems (CDSS) are formally defined as “active knowledge systems which use two or more items of patient data to generate case specific advice” [Wyatt J, Spiegelhalter D 1991]. CHAPTER 2: provides an in depth discussion of CDSS.

1.2.1 Features of CDSS

A systematic review of randomized controlled trials of clinical decision support systems used multiple logistic regression to identify four independent features which indicated improved clinical practice [Kawamoto et al. 2005]. The four features are:

- Automatic provision of decision support as a part of clinical work flow
- Provision of recommendations rather than just assessments
- Provision of decision support at time and location of decision making
- Computer based decision support

1.2.2 Functions of CDSS

Perreault & Metzger described the four key functions of a clinical decision support system in their paper, which are listed below [Perreault L, Metzger J 1999]:

2. Managing clinical complexity and details: Keeping patients on research and chemotherapy protocols; tracking orders, referrals follow-up, and preventive care.
3. Cost control: Monitoring medication orders; avoiding duplicate or unnecessary tests.
4. Decision support: Supporting clinical diagnosis and treatment plan processes; and promoting use of best practices, condition-specific guidelines, and population based management.”

1.2.3 CDSS Clinical Trials

There has been general consensus in medical literature than clinical decision support systems have the potential to improve health care and aide physicians [Balas et al. 1999]. To formally attest to this consensus a number of randomized and non-randomized controlled clinical trials have been conducted to evaluate care provider performer with and without a CDSS.

A systematic review done on a hundred such clinical trials discovered that CDSS improved practitioner performance in 62 (64%) of the 97 studies assessing this outcome, including 4 (40%) of the 10 diagnostic systems, 16 (76%) of the 21 reminder systems, 23 (62%) of the 37 disease management systems, and 19 (66%) of the 29 drug-dosing, or prescribing systems [Garg et al. 2005].

There have also been publications evaluating the different techniques used in clinical trials to evaluate clinical decision support systems [Kaplan 2001] based on the guide published by Journal of American Medical Association to using articles evaluating the clinical impact of a CDSS [Randolph et al. 1999].
1.2.4 Challenges involved in adoption of CDSS

The challenges involved in adoption of clinical decision support can be classified into various types like clinical, technical and maintenance related challenges.

1.2.4.1 Clinical Challenges

Most of the CDSS built focus on the functionality of it independently than establishing its context in situ. Another hassle is that most CDSS are built to function independent of the EMR management system. This results in additional data entry work for the doctors, which they find time consuming. Another form of clinical challenge is called alert fatigue. It is where the physician’s system is flooded with multiple alerts, such that the physician ceases to pay heed to them.

1.2.4.2 Technical Challenges

The field of biological systems and medicine is so complex and vast that it is difficult to incorporate all the available knowledge into one clinical decision support system. Apart from that security issues and maintaining the privacy of the patient’s information is extremely important.

1.2.4.3 Maintenance Challenges

The ongoing research in the field of medicine is vast and several papers are published every week. Maintaining the clinical decision support system in this situation becomes a very challenging task.

1.3 Statement of the Problem

The reinforcement of policies like Health Information Technology for Economic and Clinical Health ("HITECH") Act and Meaningful use of Electronic Medical Records policy [Ferris N. 2010] has opened the Pandora’s box of the challenges involved in processing and adding value to electronic medical records.

The electronic medical records (EMRs) are no doubt useful for billing and administrative purposes, but for the doctors it proves to be a laborious process to digitize medical records yielding no benefit to their practice or patient care [Illi 2007].

There have been attempts to build clinician decision support systems, which give doctors options as to what possible action they may take in terms of medication or diagnosis. But what is needed is a system which guides the doctor to make the decision, not one that provides possible options based on the few standard databases available at hand. The system should provide relevant, updated and automated information in order to be considered as value added service.
1.4 Statement of Objectives

The objective of this thesis is to build a clinical decision support system called Clinician Decision Support (CDS) Dashboard, which satisfies the following objectives:

- To provide doctors with relevant articles from MEDLINE, case reports, clinical trials and other de-identified electronic medical records similar to a given patient’s EMR,
- To build an automated, actionable, interactive, customizable and modular tool, with emphasis on user preferences.
- To use multidisciplinary approach amalgamating various fields like medicine, biomedicine, data mining and human computer interaction.
- To make this system accessible to all physicians, care takers and medical students, by providing a platform independent interface.

Amalgamating the knowledge published by researchers for decades along with the knowledgebase of existing patient cases, will help provide doctors with better context while attending to their patients, and ultimately result in better patient care. It will also take information technology one step closer to being integrated with medicine and in turn help physicians and care takers embrace technology in their daily practice with lesser resistance.

1.5 Overview of Thesis

This thesis is organized as follows. CHAPTER 2: provides a detailed background of clinical decision support systems, stating their various definitions and methodologies and the drawbacks present in the existing systems. CHAPTER 3: states the need of the Clinician Decision Support Dashboard and describes the working of the CDS Dashboard. A user study was conducted on the CDS Dashboard which is described in CHAPTER 4: The final chapter, CHAPTER 5: , describes the contributions of the CDS Dashboard and possible future work to help improve the tool.
CHAPTER 2: Clinical Decision Support Systems

Chapter 1 provided a brief synopsis of clinical decision support systems (CDSS) with a preview of its features and functionalities. This chapter provides a more detailed overview of the various definitions of CDSS, the general architecture, various methodologies that can be used to build a CDSS, the taxonomy provided in the literature, a few examples of existing clinical decision support systems and the need for the CDS Dashboard.

2.1 Definitions of CDSS

The literature provides several different definitions of clinical decision support systems which have been enlisted in the Table 1.

<table>
<thead>
<tr>
<th>Source</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wyatt J, Spiegelhalter D (1991)</td>
<td>CDSS is defined as “active knowledge systems which use two or more items of patient data to generate case specific advice”. [Wyatt J, Spiegelhalter D 1991].</td>
</tr>
<tr>
<td>Musen et.al (1995)</td>
<td>CDSS is defined as any piece of software that takes information about a clinical situation as inputs and that produces inferences as outputs that can assist practitioners in their decision making and that would be judged as “intelligent” by the program’s users [Musen et.al 1995; Musen et.al 1997].</td>
</tr>
<tr>
<td>Miller and Geissbuhler (1999)</td>
<td>CDSS provides diagnostic decision support as a computer-based algorithm that assists a clinician with one or more component steps of the diagnostic process [Miller and Geissbuhler et.al 1999].</td>
</tr>
<tr>
<td>Sim et.al (2001)</td>
<td>CDSSs are defined as “software that designed to be a direct aid to clinical decision-making, in which the characteristics of an individual patient are matched to a computerized clinical knowledge base and patient-specific assessments or recommendations are then presented to the clinician or the patient for a decision” [Sim et.al 2001].</td>
</tr>
</tbody>
</table>

Table 1. Selected definitions of Clinical Decision Support Systems (CDSS)
2.2 General model of CDSS

The general model of a clinical decision support system published in literature is depicted in Figure 4[J. Reggia 1981; M. J. Lincoln 1999]. The main architectural components of the model include the inference mechanism and the knowledgebase.

The system can take various types of inputs – clinical signs, symptoms, laboratory results, etc. based on the type of system built. A knowledge base is built for a specific application with all the related data. The inference mechanism uses rules to compare the clinical signs, symptoms and laboratory results with the available database knowledge to make diagnostic and therapeutic recommendations. Most of the applications mentioned above have some type of specialized knowledgebase. The main drawback with knowledge bases is that constructing them takes an enormous amount of time and effort.

![Figure 4. General Model of CDSS](image)

2.3 Taxonomy of CDSS

The literature describes a wide variety of clinical decision support systems, which vary in design, structure, methodologies and function. Ida et.al retrieved and analyzed 150 English language articles published between 1975 and 2002 that described different computer systems built to assist clinicians, nurses and patients by providing clinical decision support. These 150 articles included 27 descriptive reports, 27 non-randomized evaluations, and 96 randomized trials.
The final taxonomy created consisted of 95 descriptors along with 24 descriptive axes grouped into 5 broad categories as shown in Figure 5 [Sim et. al 2003; Berlin et. al 2006]. These axes are: Context, Knowledge and Data Source, Decision Support, Information Delivery, and Workflow. Figure 6 gives a more detailed description of each descriptor in the axes in the axes.

The authors enlisted three primary uses for the taxonomy.

- Describe an individual clinical decision support system in a standard format.
- Categorize the existing CDSSs and the ones being developed and evaluated.
- Use the taxonomy’s descriptors as potential explanatory variables in a meta-regression on the CDSS success.

Figure 5. Overview of Taxonomy Axes. This figure illustrates how the 24 taxonomy axes are related to the CDSS workflow and to each other. The ☺ and ☻ symbols denote human and possible human roles respectively [Sim et. al 2003].
2.4 Methodologies to build a CDSS

The inference mechanism shown in Figure 4 is one of the most important components of the clinical decision support system architecture. Different methodologies could be used to build the inference mechanism: Bayesian network, Neural Network, Genetic Algorithms, Rule-Based System, Logical Condition, Casual Probabilistic Network, etc.
2.4.1 Bayesian Network

A Bayesian network is a graphical model for probabilistic relationship amongst variables [Jensen et. al 1996]. Bayesian networks are a popular representation for encoding inexpert knowledge in an expert system. In clinical decision support systems, diseases and symptoms are variables with probabilistic relationship between them.

The system, however, becomes too complex for multiple symptoms and related conditions.

Some of the popular clinical decision support systems that use Bayesian networks are Iliad system [Warner et. al 1988], DXplain [Barnett et. al 1987] and SimulConsult [Segal 2004].

2.4.2 Rule Based System

Rule based systems are based on the knowledge of domain experts represented in the form of expressions that can be evaluated known as rules. In this case, physicians can express all their domain knowledge in form of various rules, for example, “If the patient has a family history of diabetes, he has a probability of having diabetes as well”. Based on the input provided to the system, these rules are evaluated and diagnosis is suggested.

The main disadvantage of rule-based system is the time and effort taken to encode all the domain knowledge into rules. Another disadvantage is that the system must be constantly updated with new knowledge rules.

One of the earlier clinical decision support systems, MYCIN [Shortliffe et. al 1976; Buchanan et. al 1984] was a rule-based expert system. Following MYCIN, in the 1970s there was another popular rule based system ONCOCIN [Shortliffe et. al 1981] that was developed to reduce the number of clinical trial protocol violations.

2.4.3 Casual Probabilistic Network

The Casual Probabilistic Network is based on the cause and effect relationship. In a clinical causal probability network the nodes signify patient symptoms, patient states or disease categories. The network traces the path from symptoms to disease using probability factors and tries to find the path with the highest probability. This network, like the Bayesian network, becomes too complex with a large number of symptoms or nodes.

CASNET [Kulikowski et. al 1982], which was a clinical decision support system to diagnose glaucoma, used the casual probabilistic network by building a hierarchy of nodes, splitting them up into symptoms, states and diseases.
2.5 Examples of CDSS

This section describes some of the important clinical decision support systems.

2.5.1 MYCIN

One of the earlier, well established clinical decision support systems was MYCIN dating back to 1974 [Shortliffe et. al 1976; Buchanan et. al 1984]. It is a rule based system which advises physicians regarding the selection of appropriate antimicrobial therapy for hospital patients with bacterial infection.

The MYCIN has three main components or sub programs which is depicted in Figure 7:

- Consultation System: It helps choose the appropriate drug or combinations of drugs based on the amalgamation of information provided by the physician and the knowledge. The knowledge is represented in the form of rules which have preconditions called premises, which if true, permits a conclusion to be made or an action to be taken. An example of a rule called MONITOR is shown in Figure 8.
- Explanation System: It is used to provide explanation or respond to any queries the user might have. This interactive capability helps build faith in the system for the physicians.
- Rule Acquisition System: It acquires decision criteria during interactions with an expert and codes them for future use. This is especially useful when the physician finds that a rule is missing, he can input it into the system.
Figure 7. The diagram demonstrates the flow of control and flow of information within the MYCIN System. The three subprogram components are enclosed in boxes. Control passes from one sub program to another as shown by heavy arrows. Light arrows indicate program access to information used by the system. The program’s knowledge base is contained in a corpus of rules shown on the right [Shortliffe et al. 1976; Buchanan et al. 1984].
Figure 8. Flow chart describing the rule MONITOR which analyzes a rule and decides whether it applies in the clinical situation under consideration. Each condition in the PREMISE of the rule references some clinical parameter, and all such conditions must be true for the rule to be accepted [Shortliffe et. al 1976; Buchanan et. al 1984].
2.5.2 DXplain

DXplain evolved in the later 1980s, as a system which aimed to provide clinical decision support for physicians with no computer expertise [Barnett et. al 1987]. Like MYCIN, DXplain also had a knowledge base. It would accept a list of clinical manifestations from the physicians and then propose not only diagnostic hypotheses but also offer a possible reasoning based on the symptoms and conditions from the knowledge base.

The authors believed that DXplain served two main purposes:
- Remind physicians that other possible differential diagnoses existed for the given symptoms.
- Provide a possible explanation for the eliminated diseases.

Figure 9 shows a snapshot of a typical DXplain session. The user interacts with the system by providing the requested input and the possible diagnoses are shown.

![Typical DXplain session](image)

Figure 9. Typical DXplain session. The program first asks the user some basic questions and then the medical terms related to the patient’s condition. The show command is used to display the list of diseases which may explain these symptoms or terms [Barnett et. al 1987].
One of the main disadvantages of DXplain is that the knowledge base is incomplete.

**2.5.3 ISABEL**

Similar to the systems described above, ISABEL was developed in 2002 as a differential diagnostic aid with a focus in pediatrics. ISABEL has a large knowledgebase of various textbooks relating to pediatrics. It also provides doctors with reminders of different types of differential diagnosis conditions that may exist relating to the symptoms. Figure 10 shows the user input screen, where the physician can enter the clinical features relating to the patient. Figure 11 shows the output screen that lists all the possible differential diagnoses.

A two-stage study of ISABEL was done in acute pediatric units in two teaching and two district general hospitals in southeast of England [Ramnarayan et. al 2003]. It was seen that in some cases, the final diagnosis was present in the differential diagnoses list, but in other cases the suggestions made were misleading.

![Figure 10. User Input screen where user can enter all the clinical features for the patient [Ramnarayan et. al 2003].](image-url)
2.5.4 Other CDSS Systems

Apart from the systems described above, there are numerous other clinical decision support systems, which have been developed over the past decades.

2.5.4.1 INTERNIST I

The INTERNIST was a clinical decision support tool built in 1970, followed by the INTERNIST I that was built at the University of Pittsburgh in 1974 [Pope et. al 1975]. It was mainly built for diagnosis of complex problems in internal medicine.

2.5.4.2 ABEL

The Acid-Base and ELectrolyte program (ABEL) was developed at the Laboratory of Computer Science in the 1980s [Paul et. al 1982]. ABEL was designed as an expert system employing casual reasoning for management of electrolyte and acid base derangements.
2.5.4.3 ONCOCIN

ONCOCIN was developed at Stanford University, to assist physicians with cancer patients receiving chemotherapy [Shortliffe et. al 1981]. It used a customized flowchart language to model decisions and sequencing actions over time, using a customized flowchart language. It was a rule based decision making oncology system.

2.5.4.4 QMR

Quick Medical Reference (QMR) was one of the successful systems in the 1980s, which was commercialized. QMR was originally developed by University of Pittsburgh and can be defined as a “diagnostic decision-support system with a knowledgebase of diseases, diagnoses, findings, disease associations and lab information” [Miller et. al 1986]. It was designed for three purposes:

- An expert consultant program
- Electronic textbook
- Intermediate level spreadsheet for combination and exploration of simple diagnostic concepts.

2.6 Need for Clinician Decision Support Dashboard

This thesis describes the prototype of a type of CDSS called Clinician Decision Support (CDS) Dashboard, which is based on several interactions with medical students and clinicians from Carilion Clinics and the other CDSS studied extensively. We noticed the following drawbacks in the existing systems:

- It was observed that none of the existing clinical decision support systems used the abundant existing knowledge manifested in existing patient records.
- Utilizing just the standard databases or encoded static rules, may produce outdated and misleading results.
- Most systems require the clinicians to enter all the patient details and symptoms once again into the CDSS, which may be a time consuming and laborious task.
- Most of these systems are designed only for users highly familiar with computer systems and not for naïve users.

Hence, the Clinician Decision Support Dashboard was built to address these concerns.
CHAPTER 3: Clinician Decision Support Dashboard

The aim of the Clinician Decision Support (CDS) Dashboard is to provide interactive, automated, actionable EMR text-mining tools that help improve both the patient and clinical care staff experience. The CDS Dashboard helps physicians find de-identified electronic medical records similar to their patient's medical record thereby aiding them in diagnosis, treatment, prognosis and outcomes. Of particular value in cases involving complex disorders, it also allows physicians to explore relevant medical literature, recent research findings, clinical trials and medical cases. This chapter talks in detail about the structure of the clinician decision support dashboard, the input provided to the dashboard, the text similarity engine used, and the output produced by the dashboard.

3.1 Structure of Clinician Decision Support Dashboard

The CDS Dashboard is generic, yet customizable, modular and extensible. It is designed to run concurrently with existing electronic medical record software and provide doctors with pertinent information with respect to the current patient’s electronic medical record they are viewing. The pertinent information includes de-identified electronic medical records of other patients who have faced similar medical problems, relevant medical literature, case reports and clinical trials. The clinical decision support system has been designed such that the doctors can customize as to what patient information should be displayed on their screen and from which sources they want relevant information drawn and in which order. One of the main advantages of the CDS is that it allows the doctors to control how they want to use the software.

Figure 12 depicts the flow of sequence of the clinician decision support dashboard. Typically the input to the system would be the electronic medical record of the patient, which would be automatically fetched from the EMR management system, based on the current medical record the doctor is viewing. But since this is a prototype system, the user has to explicitly fetch the EMRs and the EMRs for this prototype have been created from local and/or national sources. Apart from the EMR, the user preference chosen by the user are also fed as input into the system. The input data goes through a series of preprocessing steps which is very crucial to producing relevant results, as shown in the Query Assembly and Conditioning block in the diagram. This preprocessed input is then sent to a text similarity engine (eTBlast), which compares the processed EMR against several standard databases of medical literature, clinical trials and other de-identified electronic medical records.
3.2 Input

The user interface of the CDS displays excerpts from the patient’s electronic medical record as per the user preference. Various segments of the electronic medical record are displayed, for example the past medical history, past family history, etc. and with each segment has a checkbox associated with it. This allows the user to select the segments of the electronic medical record of the patient that should be part of the query. The user can resubmit the query any number of times by modifying which segments are to be included in the query and which are not. There may be some segments of the electronic medical record that the user has chosen not to be displayed, but they still have the option of including them in the query based on which ‘similar’ results from selected resources will be displayed. If there is a standard, preferred set of segments then these are can be analyzed automatically to minimize time required by the user.
3.2.1 Input Data Conditioning

After the user has constructed his query (the parts of the EMR to be included for analysis), we do not directly feed it into the similarity engine for a number of reasons. Some of them being that the query is its raw form may contain ‘noise’, including, for example, a number of abbreviations both standard and non-standard, stop words and negative terms. The CDS performs many preprocessing steps as discussed below.

3.2.1.1 Personalized Acronym Analyzer

Doctors, physicians and nurses have their own short forms and abbreviations they use while taking down notes about patients or making entries into the medical record for speed and convenience. Some of the acronyms are standard medical abbreviations. Others are non-standard acronyms the medical provider has developed over the course of years of practice as a matter of standard practice. The personalized acronym analyzer in CDS has been built keeping these factors in mind. It has a medical dictionary interface where the doctors can choose the acronyms they generally use and can also add the extra acronyms not present in the medical dictionary. The interface has split the acronyms alphabetically for convenience and it also allows the user to add different expansions for existing acronyms as well. The health care professional can make these entries at any time with the customized information retained for each professional. Some of the electronic medical record systems already have this feature. So in order to prevent repetitive work, this feature can be directly tied into the system and these entries can be exchanged with the CDS database.

Figure 13. EPIC has a acronym feature called SmartPhrase List analogous to the Personalized Acronym Analyzer in CDS Dashboard. The CDS Dashboard has available a standard list of acronyms the user can choose from.
The purpose of this feature is to enhance the performance of the text similarity engine by ensuring that the query is optimized. Though the EMR may contain medical abbreviations that may be different from those abbreviations used by the large variety of authors of the medical literature, this mapping maximizes the probability of finding the most appropriate literature that is relevant to the clinician for a given patient.

### 3.2.1.2 Stop Words Eliminator

Stop words elimination is an important component in most information retrieval and data mining systems. Apart from eliminating the generic stop words, we also eliminate medical stop words, which occur so frequently that their value in searching is very limited. There is also a provision for the user to enter words and build a customized stop word list thus further improving the performance of the CDS Dashboard for a given user.

### 3.2.1.3 Negation Eliminator

It is a common occurrence in electronic medical records to record every detail and observation about the patient and make notes of symptoms present and absent. The symptoms that are not present, if considered for the similarity searching may influence the engine to give wrong or irrelevant results. So it is essential to have a component that has natural language processing capabilities that removes the negative statements or phrases from the electronic medical record before sending it to the text similarity engine.

### 3.2.2 User Preferences

The CDS has a user preferences section, which allows doctors to personalize the information displayed on their screen. So each login will have a customized display depending on user preferences. Figure 14, displays the user preferences and also allows the user to modify the details to be displayed and their order. The user preferences page allows you to choose the following:

- **Word Cloud**
  - Option to show or hide word cloud
  - Multiple color or single color
  - Multiple fonts or single font
- **Patient Details**
  - Which patient details are to be displayed and in which order.
- **Sources**
  - Which sources should be used for searching similar results and in what order should they be displayed.
Figure 14. User Preferences Form allows the user to set preferences about how the EMR and the corresponding text similarity results are to be displayed. The user can choose the display of word cloud, the patient details from the EMR, and the sources from the relevant results are to be displayed.

3.3 Text Similarity Engine

3.3.1 eTBLAST Similarity Engine

The “Garnering Innovation” group developed the eTBLAST text similarity engine [Errami M et. al 2007, 2010; HR Garner et. al 2007; Z Sun et. al 2010; Tara et. al 2009]. This similarity engine can be accessed via JSON (Java Script Object Notation) calls, given the input text and the database to be accessed. The electronic medical record, after all of its preprocessing conditioning by the personalized acronym analyzer, stop words eliminator and negation eliminator, is given as input to the eTBLAST similarity engine. The eTBLAST search engine has a wide variety of public and custom databases to which the electronic medical record can be compared. For CDS
Dashboard we chose the most pertinent databases namely, Medline, case reports and clinical trials. Apart from these, a database of electronic medical records was constructed for the purpose of the CDS Dashboard and indexed into eTBlast. This database of existing de-identified patient electronic medical records is constructed from local and/or national sources.

### 3.4 Output

The output user interface has been divided into two segments. One segment displays the details of the electronic medical record of the patient selected for analysis by the user based on user preferences. This ensures that only the relevant information of interest to the clinician is presented. Each segment of patient’s detailed EMR is displayed as a collapsible section so the doctor can expand any section he wants to view in more detail.

The second half of the screen displays the relevant articles from Medline, case reports and clinical trials and other similar de-identified EMRs, as chosen by the user. In case the user wants to customize the similarity search further and base the search only on certain segments of the patient’s electronic medical record, the user can use the checkboxes to select the segments they would like to include in the search and submit a fresh query.

The bottom part of the output contains the word cloud, which is discussed in detail in Section 3.4.5. The word cloud contains the important phrases present in the text of the window. On mouse over, it displays the context of the words, which can be clicked on for more detailed results.

Figure 15 shows a screenshot of the output discussed above. The similarity search results show succinct results of the top three matches in each category along with important keywords and direct links to Medline. These results are based on user preferences. Each result also has a ‘See More’ option, which displays more detailed results when clicked on as shown in Figure 16 and Figure 17. After clicking ‘See More’, the browser goes to a new page, which displays the top five results in detail and the top 100 results in a tabulated format.

The detailed results include the similarity score, the rank of the result, the title, a link to PubMed and a detailed abstract. The tabulated results contain the PMID, the similarity score and the title of the article. If the user feels that the article is relevant, he can click on the title, which is hyperlinked to Medline.
Figure 15. Typical user interface customized according to user preferences. The user interface contains the patients EMR automatically fetched from the EMR Management System and displayed according to user preferences. The results from similarity search are displayed on the right hand side and the word cloud is displayed below.
Figure 16. On clicking ‘See more results’, detailed results are shown which includes the relevency score and the common words being highlighted. The detailed abstract is shown for the top five results.
Figure 17. On clicking ‘See more results’, apart from the detailed abstracts for top five results, the top hundred relevant articles are displayed with direct links to PubMed.

3.4.1 Relevant articles from Medline

Medline contains abstracts and journal citations for biomedical literature. It has a large database of over 18 million references to articles published in more than 5,500 current biomedical journals [Medline Fact Sheet]. Medline indexes over 600,000 new articles a years, so it is essential that this, and the other databases be updated frequently, in this case, weekly. These abstracts have been indexed by the eTBlast engine. If the user has selected the modules, which displays relevant articles from Medline, then based on the preprocessed EMR, eTBlast launches a similarity search and displays the relevant abstracts along with their similarity scores, which provide users with an indication of relevancy. This provides the users with the latest research trends in the area related to the patient’s condition. It helps them stay abreast of the latest discoveries or findings in the given area.
3.4.2 Relevant Case Reports

PubMed, apart from abstracts from Medline, has a number of case reports, which are searched by eTBlast. Case reports contains highly detailed information about symptoms, signs, treatment and other details of patients that were created and reported by clinicians in the past as a canonical reference for a given patient. The relevant case reports module provides doctors with other documented cases similar to their patient as this information may aid the clinician in diagnosis, treatment or predicting outcomes. This may be particularly valuable for patients with complex and/or multiple indications.

3.4.3 Relevant Clinical Trials

Clinical Trials from the ClinicalTrials.gov clinical trials database and have been indexed by the eTBlast engine [Mi et. al 2005]. These are particularly useful to doctors when they wish to have an overview of clinical trials that were conducted or ongoing clinical trials for which their patients can potentially be eligible for participation. This feature could enable the doctor to participate in these trials and it could help patients in need, either with new treatments or financially.

3.4.4 Relevant De-identified Electronic Medical Records

The existing electronic medical records, which are present in the firewall-protected database of the hospital or clinic, can be de-identified, indexed and stored, in preparation for searching by eTBlast. For the prototype built for this thesis, the electronic medical records have been created from local/national sources. The CDS system was designed to be implemented on a single Linux-based server, which can be deployed at the user site to address security needs and maintained remotely. Since the EMRs are processed within the firewalls of the hospital, the security concerns are minimized. This module will help doctors identify other patients who have faced similar problems. This is particularly useful when the patient has a rare condition or a condition that may exist at elevated frequency within the population served by the given practice. This module helps identify a wide variety of patients who have had similar symptoms based on the text in the electronic medical record, but may have been diagnosed with similar or different indications.

3.4.5 Word Cloud

The word cloud is formally defined as ‘a visual representation for text data, typically used to depict keyword metadata (tags) on websites, or to visualize free form text’ [Halvey et. al 2007]. It is another optional feature provided by CDS Dashboard. It presents the physician with an overview of the important phrases in the electronic medical record of the patients and the similarity resources chosen by the doctor. The word cloud is also customizable in terms of its color and font. The text, before being displayed graphically in the word cloud, undergoes the standard procedures of stemming, stop words removal and negation elimination. What makes this word cloud unique is that, on mouse over of the terms/phrases in the word cloud, it displays a small pop up window, which gives the context of the term/phrases in the document as shown in Figure 18. If you click any of the contexts displayed, it triggers a search to find other de-
identified EMRs, articles from Medline, case reports and clinical trials containing the context phrase. Knowing that clinicians must make the most with their time with a patient, this data projection is designed to quickly provide pertinent information in a way that enables to clinician to focus on that which is the most important.

Figure 18. Word cloud contains important phrases. Bigger font implies higher the frequency of the phrase. On mouse over, a small window displays the context of the phrase. When user clicks on phrase, or any of the context phrases a search is launched on various databases – Medline articles, Case Reports, Clinical Trials and EMRs and matching results are displayed.

3.5 Sequence Flow

The sequence flow of accessing the current prototype of CDS Dashboard, accessible at http://emrdashboard.vbi.vt.edu, is described in this section. Figure 19 displays the homepage of the Dashboard. The temporary login details are username: vbiemr and password: iccha.

Once the user successfully logs in the home page is displayed as in Figure 20. The user can choose to do any of the following:

- Customize the Personalized Acronym Analyzer.
- Set the user preferences.
- Search for a patient.
- Use the eTBlast feature.
- Log out.

If the user wants to perform the similarity search on the EMR of a particular patient, the user can search for the patient by clicking on Search Existing Record. The search screen to look up a patient in the CDS Dashboard is similar to the search screen of EPIC so that it ensures that the user is in his comfort zone as shown in Figure 21. The user can enter details in either one or more of the fields: id, patient name, date of birth or gender. The various patient EMRs which
match the search criteria are displayed in a table. The user can click on any of the patient ids and launch the similarity search.

Figure 19. Screen shot of the home page of the CDS Dashboard. The Dashboard can be accessed at http://emrdashboard.vbi.vt.edu.
Figure 20. Home page after the user logs in. The user can start by either setting up the personalized acronym analyzer, or searching for patient record, or using the eTblast feature directly or setting user preferences.

Figure 21. Patient Search Interface. The user can search for a patient using their id, name, date of birth or gender. The interface is built similar to EPIC patient search interface so that the user is at ease. The blue table displays the results from the patient search.
Figure 22. Help Section has video tutorial with running commentary below for new users.
的帮助部分还提供了一个逐步教程和屏幕截图，适用于新用户。

图23。帮助部分还提供了一个逐步教程和屏幕截图，适用于新用户。

内容从病人的电子病历中提取，显示结果如图15、图16、图17和图18所示。用户偏好表如图14所示。对于新用户而言，有一个单独的帮助部分包含视频教程和文字教程。如图22所示，视频教程解释了用户如何导航并使用仪表板，同时运行文字评论。图23展示了新用户提供的文字教程，包含步骤步骤指令和相应的屏幕截图。

此外，CDS仪表板还提供了一个额外的功能，即对医学文献、案例报告、临床试验以及脱敏电子病历的标准数据库进行非结构化文本相似性分析。非结构化文本经过与患者电子病历相同的预处理步骤后，文本相似性算法启动。这对于医生想要表达他们的思维过程或分析不在患者电子病历中的内容时非常有用。图24显示了这个特性的屏幕截图。

图23。帮助部分还提供了一个逐步教程和屏幕截图，适用于新用户。

内容从病人的电子病历中提取，显示结果如图15、图16、图17和图18所示。用户偏好表如图14所示。对于新用户而言，有一个单独的帮助部分包含视频教程和文字教程。如图22所示，视频教程解释了用户如何导航并使用仪表板，同时运行文字评论。图23展示了新用户提供的文字教程，包含步骤步骤指令和相应的屏幕截图。

此外，CDS仪表板还提供了一个额外的功能，即对医学文献、案例报告、临床试验以及脱敏电子病历的标准数据库进行非结构化文本相似性分析。非结构化文本经过与患者电子病历相同的预处理步骤后，文本相似性算法启动。这对于医生想要表达他们的思维过程或分析不在患者电子病历中的内容时非常有用。图24显示了这个特性的屏幕截图。


Welcome Doctor!

Patient Record:

Search Case Reports  Search Medline  Search Other EMRs  Search Clinical Trials

Example:

1. Copy and paste the sample medical record given below into the textbox provided.

Sample Medical Record:

Essentially, Mr. Correa is a 60 year old male who noted the onset of dark urine during early January. He underwent CT and ERC at the St. Josephs Medical Center on April 28. He was found to have a large, bulging, extrinsic mass in the lesser curvature of his stomach. Fine needle aspiration showed atypical cells, positively reactive mesothelial cells. On CT on April 14, showed a 12 x 8 x 8 cm mass in the region of the left lobe, and appeared to be from the lesser curvature of the stomach or left liver. He denied any nausea, vomiting, anorexia, or weight loss. He states that his color in urine or in stool is normal. PAST MEDICAL HISTORY: He has hypertension and nephrolithiasis. PAST SURGICAL HISTORY: Status post left kidney stones x 2, and he has had a parathyroid surgery. ALLERGIES: He has no known do. MEDICATIONS PRIOR TO ADMISSION: Hydrochlorothiazide 25 mg q.d., Candesartan 0.1 mg p.o. q.d., diclofenac 5 mg p.o. q.d. HOSPITAL COURSE: Basically, pt underwent a subtotal gastrectomy on the 7th of June by Dr. Koteikokshiff. He had an uncomplicated course and he was transferred. Advanced his diet on postop day # 4 to a transitional diet. His PCA was discontinued on postop day # 4, and essentially he was started on his pre-op medications on the postop day # 5. PHYSICAL EXAMINATION: CHEST: Clear; Ht: Regular; abd: INCISION: Clean, dry and intact. No drainage. VITAL SIGNS: He is afebrile and otherwise vital signs are stable. He is having good p.o. intake on post op diet and he is moving his bowels. DISPOSITION: He is going to a rehabilitation facility until he is able to live independently. DISCHARGE MEDICATIONS: Same as pre-op, with the addition of Roxitin. Dictated By: THAMETO DOYLE, M.D. GS43 Attending:

PNO A. KOTIEOKSHIFF, M.D. RF6 ZY523/1522 Batch: 99974 Index No. YPKIAITZX9 D: 06/13/99 T: 06/13/99 K9

2. If you want to search for similar articles present in Medline, click on "Search Medline".

3. If you want to search for other similar electronic medical records, click on "Search Other EMRs".

Figure 24. Free Text eTBlast search segment. The user can enter any text and launch a text similarity search against other EMRs, literature from Medline, Case Reports, and Clinical Trials.

3.6 Technologies used

The electronic medical records and patient details database was created and stored using MySQL database which formed the local backend for the dashboard. The interface is built using PHP, JavaScript and JQuery. The design is very modular, so that the tool can be customized very easily, both by the users and the future developers. For the text similarity, eTBlast module is used which is independently located on another server. The eTBlast is provided with the de-identified EMRs to be indexed and stored. Whenever the user launches a query, the preprocessed query is sent to eTBlast using JSON and results are retrieved. The relevant post processing is done, before displaying the results to the users.
CHAPTER 4: USER STUDY OF CLINICIAN DECISION SUPPORT DASHBOARD

4.1 User survey details

A talk on Clinician Decision Support (CDS) Dashboard was presented to the medical students at Virginia Tech Carilion School of Medicine and Research Institute (VTC) followed by a live demo of the tool. After that the students were given time to explore and use the CDS Dashboard. At the end of this session a survey was conducted to gather their opinion and experience with the Dashboard. The medical students who participated were in their first and second year of study.

4.2 User Survey Questions

The survey consisted of both free text questions as well as numeric rating questions. The medical students were asked to evaluate and rate the usefulness of the tool for physicians and students. They were also asked to rate the user friendliness of the tool from a scale of 1 to 10 with 1 being the least user friendly and 10 the most user friendly.

The free text questions included the student’s opinion on the positives of the tool and the negatives of the tool. It also included ideas for new features they would like to see in the tool and any other additional comments they had.

These questions would help analyze the tool from the user’s perspective and plan for possible future improvements to it or additional new features.

Figure 25 shows a screenshot of the user survey questionnaire conducted. A total of 38 responses were obtained and were studied.
Figure 25. User Survey on the Clinician Decision Support Dashboard.
4.3 Usefulness and Use Friendliness of the CDS Dashboard

We surveyed 38 students from VTC on the tools’ ability to aid physicians in patient care, provide medical students with a valuable learning tool, and to rate the ease of use or “user-friendliness” of the tool as shown in [Error! Reference source not found.], [Error! Reference source not found.], and [Error! Reference source not found.]. Each survey component was scored on a 10 point scale by the student and we assumed that a score of 5 or higher for each component constituted a positive evaluation of the component.

Overall, the survey responses revealed positive responses in each component. For the evaluation of the tools’ effectiveness for the physician in the clinical care setting, the tool showed 89% of responses grading a 5 or better. In the evaluation of tools’ effectiveness as a learning aid for medical students, it received 81% positive feedback. In the evaluation of the tools’ user-friendliness, it also received 81% positive feedback.

| Total number of students who took the survey | 38 |
| Number of students who considered the Dashboard a useful tool for doctors* | 34 (89%) |
| Number of students who considered the Dashboard a useful tool for med students* | 31 (81%) |
| Number of students who felt the Dashboard was user friendly* | 31 (81%) |

Table 2. Statistics of user survey conducted at Virginia Tech Carilion School of Medicine
Figure 26. Survey component rating the effectiveness of the tool within the clinical setting.

Figure 27. Survey component rating the effectiveness of the tool within the medical educational setting.
4.4 Positives and Negatives of the CDS Dashboard and Suggested New Features

The medical students were asked to provide additional unstructured comments regarding their own thoughts of the tools’ effectiveness in the clinical setting. We received a wide variety of invaluable responses ranging from difficulties in implementation, to usefulness, ideas on how to make the tool better, as well as features particularly seen to be advantageous within the tool structure. A summary of the comments received is enlisted in Table 3 and a more detailed listing is found in Appendix A.
<table>
<thead>
<tr>
<th>Benefits of the Tool</th>
<th>Areas to Improve</th>
<th>Suggested Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>“You can customize, and look up clinical trials from a large and respectable resource.”</td>
<td>“Too much information presented at times”</td>
<td>Link to outside institutions such as Hospitals, Schools, CDC, and Local Health Department</td>
</tr>
<tr>
<td>“immediate view of relevant case studies - most useful when dealing with unusual combinations of symptoms and rarer diagnoses”</td>
<td>“Research-focused interface is not as useful for students who are trying to learn the standard of care, not the latest in research.”</td>
<td>Summary of current standard of care</td>
</tr>
<tr>
<td>“Obviously, it would be awesome to have such a powerful search integrated into an EMR.”</td>
<td>“slow speed”</td>
<td>Include patient demographics in search function</td>
</tr>
<tr>
<td>“ability to enter free text ability to customize the word cloud”</td>
<td>“Realized benefit of the tool needs to outweigh the time needed to learn and operate”</td>
<td>Add increased priority to Epidemiologic Data</td>
</tr>
<tr>
<td>“As an academic tool, I enjoy integrating an article search with the case I am viewing.”</td>
<td>“Also a print to PDF or Email the article function might be good.”</td>
<td>Incorporate links to Dynamed, UptoDate, or MDConsult</td>
</tr>
<tr>
<td>“Ease of use; very intuitive and simple interface. Puts useful information right out in the open”</td>
<td>“Would like a more sophisticated interface for lab results; Put in pertinent lab summaries into the main page, then have a way to increase the level of detail for each lab”</td>
<td></td>
</tr>
<tr>
<td>“customizeability is great; continued exposure to new information and clinical treatments have the potential to help time-constrained physicians continually improve their knowledge and exposure to treatment alternatives. As a student, this will facilitate learning with connections to other cases, primary and secondary literature - I really look forward to being able to use it in this regard.”</td>
<td>“medications list too messy to use. should be in a list format”</td>
<td>Display a map of searched output results to the relevant patient chart input</td>
</tr>
</tbody>
</table>
“I suspect that the real value added here is for clinicians who are stumped -- or just looking for a place to start -- with any given case. For example, I like the idea of being able to type out my thoughts on a case, pasting them into the tool, then having the tool return related literature. True, it's possible to conduct similar searches with PubMed and Google Scholar, but this tool seems to offer greater granularity for inquiries that pertain to unique cases. I would imagine that enhancing the heterogeneity of information in mind at the beginning of any case will prove useful for expanding the scope of one's medical intuition and stave off premature marriage to any given diagnosis.”

“I don't know yet!”

“It is online and somewhat easy to use.”

“The layout is quick and easy to scan over - a lot of pertinent data all on one page. The journal articles tailored specifically for the patient's complaints/symptoms seem like a very useful tool to have readily available (as well as the case reports and clinical trials).”

| “I suspect that the real value added here is for clinicians who are stumped -- or just looking for a place to start -- with any given case. For example, I like the idea of being able to type out my thoughts on a case, pasting them into the tool, then having the tool return related literature. True, it's possible to conduct similar searches with PubMed and Google Scholar, but this tool seems to offer greater granularity for inquiries that pertain to unique cases. I would imagine that enhancing the heterogeneity of information in mind at the beginning of any case will prove useful for expanding the scope of one's medical intuition and stave off premature marriage to any given diagnosis.” | “I don't know yet!” |
| “It is online and somewhat easy to use.” | |
| “The layout is quick and easy to scan over - a lot of pertinent data all on one page. The journal articles tailored specifically for the patient's complaints/symptoms seem like a very useful tool to have readily available (as well as the case reports and clinical trials).” | |

**Table 3. Summary of Free Text comments received as a part of the User Survey on CDS Dashboard enlisting the positives and negatives of the tool, along with new features the medical students would wish to see in the Dashboard.**

### 4.5 Comparison to other resources

Studies have shown that the time utilized in accessing clinical information for patient care is significantly improved in physicians using electronic resources in practice instead of other forms of media [Alper et. al 2005]. As electronic media becomes more accessible within the clinical practice, it will become essential for physicians to find resources that not only accommodate their practice, but also provide them with the information that will need in order to make appropriate clinical decisions.

Currently, resources such as DynaMed, UptoDate, and MD Consult have become very popular among health care professionals in practice today with many viewing UptoDate as the preferred eResource in the clinical environment [Goodyear-Smith et. al 2008]. However, the differences between these tools are subtle. Like the CDS Dashboard, they each provide access to research and standards of patient care. However we feel the implementation of this CDS Dashboard tool
will provide additional, extensible dimensions to this growing field of electronic medical resource utilization.

First, the CDS Dashboard tool has the sole distinction of being the only electronic medical resource that acquires its search input directly and automatically from patient data. Presumably this function will reduce query formulation time required of the clinician as well as remove a degree of search bias expected in clinical practice when each query is custom formulated. Instead of functioning retroactively with acquiring information on an initial diagnosis as seen in other tools, CDS Dashboard tool will proactively engages the physician in the clinical decision process.

Second, the CDS Dashboard provides immediate access to research publications and advances in standards of care in a manner that does not require a periodical update as in the case of other commonly used tools. Further, the CDS Dashboard tool is customizable to the physician’s style of practice, something we feel will not only allow for a smooth implementation into practice, but will also provide a subtle but effective advantage of this tool over current electronic medical resources.
CHAPTER 5: CONCLUSIONS AND FUTURE RESEARCH

5.1 Other uses of tool

The Clinician Decision Support Dashboard has been built to provide useful and relevant information to physicians given a patient’s electronic medical record. This same tool can also be extended and used for other purposes.

Medical students can use this tool in various stages of their study for learning purposes. Given a particular case study, it can help them locate relevant literature or other similar cases. This will help them broaden their knowledgebase. Apart from that, medical students who are doing research can supplement their research with additional relevant material from CDS Dashboard. The study described in CHAPTER 4: , asserts the fact that this tool has been indeed found useful by medical students.

Nurses in training or students in residency for the purpose of continued education in the field of medicine and biomedicine can also use the CDS Dashboard.

5.2 Conclusions

A Clinician Decision Support System was constructed with continuous feedback from medical students at Virginia Tech Carilion School of Medicine and Research Institute (VTC). The main objective of the system is to provide clinical decision support to physicians and act as a learning aide for medical students. The CDS Dashboard was built keeping in mind the drawbacks the current systems have and the physician’s preferences.

Given a particular patient’s EMR, the CDS Dashboard will display similar bio-medical literature from MEDLINE, case reports, clinical trials and other de-identified patient EMRs. These resources are particularly helpful when the doctor has a patient with a rare condition or uncommon symptoms. These resources help the physician locate other patients who have had similar symptoms or diagnoses. These resources are continuously updated, providing the physicians with most up-to-date publications and information in the field.

The CDS Dashboard was built to be automated, customizable and modular. This ensures that the tool displays only that information which is relevant to that particular user. The tool is very user friendly and intuitive to use, which makes it easy for the physicians and students who are naïve users to use it.

A study done at VTC revealed that a very large percentage of the students found the tool to be useful for not only for physicians but medical students as well. A majority of them also found the tool to be easy to use and listed a number of features they would wish to see in the tool in the future.
This study reaffirmed the need for a tool that provides value added services to the existing EMR management system. The customizability of such a tool to each user’s preference is one of the most cited strengths of the tool by the users.

5.3 Contributions

The work on Clinician Decision Support Dashboard has brought several factors related to building a clinical decision support system to light, which were neglected in prior systems.

It has highlighted the fact that building a clinical decision support system is a multidisciplinary area of research. It is essential that the background knowledge in medicine is amalgamated with data mining techniques and human computer interaction to give users an experience which not only is beneficial but is also easy to use.

The manifested knowledge in existing EMRs has been neglected due to its inherent complexities, but with the right algorithm, this abundant resource can give the physicians a chance to learn from other existing medical cases and aide them in their current diagnoses. Similarly the information present in existing medical literature is rich and doctors do not always have time to go through external resources. A tool which brings all the relevant information together at one place saves physicians time and effort.

During the process of building the Clinician Decision Support System, one of the glaring facts which posed to be a big hurdle for the research was the lack of freely available de-identified electronic medical records for the purpose of research. In view of this situation, it is only the organizations which are affiliated with medical schools and hospitals that can carry out research in medical informatics as the necessary data is not available to every researcher who wishes to do so.

5.4 Future work

The CDS Dashboard is a stepping-stone to a much larger and well-developed platform that can be linked directly to any EMR Management System. The study conducted at VTC helped layout the future work for the Clinician Decision Support Dashboard.

The first step would be to deploy the CDS Dashboard in a live environment in hospitals and study the use of the Dashboard in real time. This would help determine how often the tool is used, by which type of doctor and how useful it is in daily practice. Apart from making it available as a web interface, making it available on mobile phones as an application may make it a quick reference tool for students.

The CDS Dashboard could be made more user friendly by separating the output interface into smaller components, followed by some user studies.

A number of new features could be added to the CDS Dashboard to make the tool better. The combination of Orange Book and MedWatch alerts can provide the users with drug-drug
interaction alerts as well as adverse medical events associated with drugs. This will provide the users with drug specific information and alerts.

To better utilize all the information present in the patient’s electronic medical record, the Dashboard could also use the image annotations and laboratory reports to provide more accurate relevant results to the user. But this component would require additional preprocessing of data to convert the data from given format to one which can be provided as input to the text similarity engine.

Customizability of the CDS Dashboard was observed to be a very important feature when analyzing the results of the user study. An additional layer of customizability could be added to the CDS Dashboard by allowing the users to add their own set of resources to which they can compare the patient data. This is useful because every hospital or medical school may have their own set of recommended resources for clinicians and medical students.

Based on the encouraging iterative feedback, the CDS Dashboard has the potential to grow and help physicians provide better health care and enable medical students to expand their knowledgebase.
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Appendix A

Free Text Comments from the User Survey conducted at Virginia Tech School of Medicine on the Clinician Decision Support Dashboard
<table>
<thead>
<tr>
<th>What are the positives of the tool according to you?</th>
<th>What are the negatives of the tool according to you?</th>
<th>Is there any specific feature you wish to see in this tool in the future?</th>
</tr>
</thead>
<tbody>
<tr>
<td>You can customize, and look up clinical trials from a large and respectable resource.</td>
<td>There needs to be many customizations for a specific search.</td>
<td>More customizations.</td>
</tr>
<tr>
<td>Links to the clinical trials</td>
<td>info overload</td>
<td>Link to outside institutions</td>
</tr>
<tr>
<td>immediate view of relevant case studies - most useful when dealing with unusual combinations of symptoms and rarer diagnoses</td>
<td>I don't know yet!</td>
<td>Making sure that the different resources associated with my patient record (relevant EMR, case reports, clinical trials, etc.) are highlighted on the screen in different colors. LOTS of type over the page is more easily recognized with colors!</td>
</tr>
<tr>
<td>In bringing up the relevant case studies and new research, it keeps us up to date.</td>
<td>There are places with large chunks of data that are hard to read that run together. More space between things will make this easier to read.</td>
<td>Integration of a drug database would be very useful, along with the addition of the med alerts data.</td>
</tr>
<tr>
<td>easy access to relevant literature</td>
<td>Research-focused interface is not as useful for students who are trying to learn the standard of care, not the latest in research.</td>
<td>summary of current standard of care for diagnosis.</td>
</tr>
<tr>
<td>Obviously, it would be awesome to have such a powerful search integrated into an EMR.</td>
<td>Not sure.</td>
<td>A dropdown box for sex selection.</td>
</tr>
<tr>
<td>Ability to look at deidentified EMRs and clinical cases. Good idea as well</td>
<td>Vast amount of information presented can be difficult to sort through.</td>
<td>Perhaps adding a search box for one of the other databases, like Dynamed or uptodate.</td>
</tr>
<tr>
<td>ability to enter free text ability to customize the word cloud</td>
<td>slow speed when searching for matches based on a specific patient, the medline results that appear on the right side of the screen do not at first glance appear relevant to</td>
<td>Search based on race, age, and gender</td>
</tr>
</tbody>
</table>
the patient's chief complaint. I think I could improve this by customizing my word cloud or checking different aspects of the EMR to search by, right?

1.) I do like the fact that I have access to multiple types of information all in one place all related to my patient's care including research, trials, and other similar case reports.

2.) It is nice having all of the relevant patient information in one place as opposed to having to click through multiple places like EPIC is structured now. It is nice being to see all labs, PMH, imaging, etc. again in one place.

Consolidated information on many levels

It may provide information overload

I would like the see the ability to override the word cloud

For patient with EPIC ID 936 the tool did seem to pick out the most important words. The freetext search that identifies similar patient could be very important for performance improvement and quality assurance project.

Demographic information wasn't taken into account. 11yo and 68 you should usually not be brought up as being similar patients for case reports or deidentified records.

A demographic filter would be the most useful feature.

- One interface has all of the information
- Relatively clean interface
- Quick access to the LATEST related literature

- Many physicians may not respond well to learning another computer based technology
- Patient information does not appear to be presented in a format that will be useful to physicians

- Better organization of patient information
-
<table>
<thead>
<tr>
<th>As an academic tool, I enjoy integrating an article search with the case I am viewing.</th>
<th>The data which informs the search may itself be incorrect and the filters may require me to go back and evaluate (check box by check box) which data I actually value from the record and which data I find suspect.</th>
<th>I wish the search linked to current epidemiologic data from the CDC and my local health department.</th>
</tr>
</thead>
<tbody>
<tr>
<td>customizeability is great; continued exposure to new information and clinical treatments have the potential to help time-constrained physicians continually improve their knowledge and exposure to treatment alternatives. As a student, this will facilitate learning with connections to other cases, primary and secondary literature - I really look forward to being able to use it in this regard. As a student looking into research - this has the possibility to highlight areas of needed investigation.</td>
<td>Not all physicians have time during the day to integrate research review or additional information searches. Saving searches for access on alternative computers (without EMR info, perhaps) would add some flexibility and encourage use with physicians who are going non-stop while at the hospital. Also a print to PDF or Email the article function might be good.</td>
<td>primary resources links - we have extensive textbooks online with carilion; a link to this would be great for students and residents looking to dig further into subspecialty information that we are not learning with general med textbooks.</td>
</tr>
<tr>
<td>I love the ability to access a lot of relevant patient information, particularly linked in with research.</td>
<td>The interface is a bit clunky right now and the limited database prevents full evaluation of the program. Many interesting and potentially useful ideas, however, it's not possible to test the skill of the text search algorithms without a broader sample.</td>
<td>A real time search bar (a la google instant) to help narrow results.</td>
</tr>
<tr>
<td>The ability to cross reference a patient with current literature, and from similar patients is helpful.</td>
<td>Potential for repeating other clinician's mistakes.</td>
<td>Addition of public health data and trends would be particularly useful in primary care. Adding in a public health reporting tool would be useful so that clinicians could see the impact of infectious disease in almost real time in their area.</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>While I am still a medical student, the text miner may be a useful resource for broadening the base knowledge that a student can access as it pertains to specific case examples. I suspect that the real value added here is for clinicians who are stumped -- or just looking for a place to start -- with any given case. For example, I like the idea of being able to type out my thoughts on a case, pasting them into the tool, then having the tool return related literature. True, it's possible to conduct similar searches with PubMed and Google Scholar, but this tool seems to offer greater granularity for inquiries that pertain to unique cases. I would imagine that enhancing the heterogeneity of information in mind at the beginning of any case will prove useful for expanding the scope of one's medical intuition and stave off premature marriage to any given diagnosis.</td>
<td>I'm not familiar with the particulars of the algorithm used to correlate the word-mix in the case to that which can be found on MedLine, but, based on the highlighted terms I've seen show up in the searches I've run so far, I wonder if each and every meaningful word (i.e., aside from articles, prepositions, etc., or more &quot;functional&quot; words) ends up being considered in correlations. Additionally, the customization with respect to abbreviations is nice but places a non-trivial work-burden on the user.</td>
<td>It would be nice to incorporate some sort of &quot;learning&quot; algorithm in the tool for handling abbreviations utilized by users. Perhaps it might be possible to develop a tool that deconstructs sentences to determine their meaning and associate these abbreviations, contractions, etc., with their root terms but this is an additional layer of sophistication. It would probably be sufficient to ask the user when abbreviations are used to clarify what was meant and then have the algorithm &quot;learn&quot; the usage of that abbreviation /for that particular user/ to be retained for future instances. Over time, perhaps your group could compile a database of abbreviations used in certain contexts and use that data to formalize methods for &quot;translating&quot; those abbreviations in future searches across your clients.</td>
</tr>
<tr>
<td>It can be very helpful when there are unknowns in the care and can be used quickly.</td>
<td>Needs to better filter the results</td>
<td>It should link to FirstConsult, which is a feature of MDConsult.</td>
</tr>
<tr>
<td>It is online and somewhat easy to use.</td>
<td>Has some restrictions. Could use more options.</td>
<td>More options/details.</td>
</tr>
<tr>
<td>Inclusion of case reports and clinical trials, overall ease of use.</td>
<td>I felt the UI could use some improvement, in particular labs and medications are difficult to read.</td>
<td>Nothing specific</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>I like that there are relevant literature and clinical trials related to the patient's case. It would be very helpful for clinicians to use this during their treatment and diagnosis.</td>
<td>The format of the whole survey is a bit complicated and condensed. I found it hard to read all the patient information especially since it was in paragraph form.</td>
<td>I would like to see more description about certain patient information, maybe as a link to click into.</td>
</tr>
<tr>
<td>Seems like an alternative to searching uptodate and giving access to patient information without the need to log on to epic.</td>
<td>It just might be easier to look up the disease rather than to go through the patient to look up information on it. Also, is the social security number necessary?</td>
<td>Can we contact the patient to recruit for a future study?</td>
</tr>
<tr>
<td>The layout is quick and easy to scan over - a lot of pertinent data all on one page. The journal articles tailored specifically for the patient's complaints/symptoms seem like a very useful tool to have readily available (as well as the case reports and clinical trials).</td>
<td>The text under the different headings of patient details seems to run together a bit, making certain parts hard to filter out or catch at a glance.</td>
<td>It may help to make the patient details easier to read by making some of the sub-headings stand out more (i.e. bolding, putting them on a new line, etc.). Otherwise the features seem adequate for the purpose of the tool!</td>
</tr>
<tr>
<td>Clean and easy to use GUI</td>
<td>The words at the bottom don't seem that helpful. It would be nice to be able to customize it for yourself as widgets. The way I would organize the page would be a bit different</td>
<td>Widgets.</td>
</tr>
<tr>
<td>I like that the relevant patient information and current medical literature along with a portion of the abstract are on the same page. Even a couple key words out of the titles of the abstracts presented might be enough to help develop a well rounded list of differentials.</td>
<td>I didn't like that the tool would pull up the Medline or PubMed article in the same window as the medical record, basically navigating away from the patient information. Also I didn't understand what the words were at the bottom of the page. They were all different sizes and didn't</td>
<td>I think it would be nice if relevant articles could either be pulled up in another window, or more fully viewed within the same pane as the patient's medical information. That way relevant facts and symptoms could be cross referenced. I think to be more useful to physicians the relevant articles that pop up</td>
</tr>
<tr>
<td>Ease of use; very intuitive and simple interface. Puts useful information right out in the open</td>
<td>Would like a more sophisticated interface for lab results; Put in pertinent lab summaries into the main page, then have a way to increase the level of detail for each lab</td>
<td>None of the listings on the right side of the page (case studies, related de-identified patients, clinical trials, etc.) seemed very helpful. Maybe this will get better as there is more data put in, but (for example), for a patient complaining of abdominal pain, there were a lot of heart disease articles on the right side, and there was a clinical trial for infants.</td>
</tr>
<tr>
<td>I like the idea of relevant case reports, as well as similar patients. I like the customizability.</td>
<td>Small changes, listed below.</td>
<td>Make the medications show up in a list versus a giant paragraph. Maybe add a select all / select none button. Perhaps for the chief complaint allow multiple boxes for multiple chief complaints, same with meds, etc.</td>
</tr>
<tr>
<td>I really like how easy it is to see other patient records and available literature. I wonder how good the program is at giving you the right pubmed articles. That would require some real use of the program to ascertain I suppose. This system could definitely help you to learn a lot about each patient.</td>
<td>The patient details are pretty wordy. I wonder if it being bulleted might make it easier to read? Particularly the medication list looks pretty messy.</td>
<td>Maybe making the history, medications and complaint easier to read, but otherwise it seems really intuitive. It might be cool for the demographics tab to calculate a BMI for you. The cloud application seems kind of silly to me, but maybe someone would find it useful.</td>
</tr>
<tr>
<td>It isn’t obtrusive. It makes information available but not in a manner that will disrupt primary attention from the patient chart. A majority of pathology, I feel, that comes into a clinic won’t require much effort on the clinicians part to effectively manage and as such, the need to access to a wide scope of information for each case is unrealistic. However, it is a good tool for those random patient cases that requires some extra research and/or requires the physician to increase their knowledge base on modern treatment and care.</td>
<td>Some of the search results are not very relevant to the patient’s chief concerns on day of admission, but rather relate to medical issues they may have had in the past.</td>
<td>It may be very attractive if the tool can link to search results in Dynamed or UpToDate. Or rather, it would be nice if the user had the option to create a customized search form module that will link to any database the user has access.</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>I really like the ability to quickly link to pubmed papers.</td>
<td>Clinical trials should be above case reports. Links to UpToDate could be helpful too. These would provide a simple basic science understanding of the material. If you could bold the font of each section within labs and physical exam, it would be easier to read.</td>
<td></td>
</tr>
<tr>
<td>It’s pretty quick to navigate through. I don’t know how many hours I logged in EPIC when I was working in an ER, but they kept continuously “upgrading” the system based on complaints that users kept submitting. When you have to handle so much info, it’s inherently hard to organize it in a convenient way, so no tool is ever going to be perfect. But this tool does seem to reduce the load to just the key pieces of data.</td>
<td>when looking through the patient’s history, I didn’t notice any way for viewing images. EMR typically contain a lot of images from various things: radiology images, scanned consent forms, EKG’s, etc. It would be good to have a link that would open up a window to show this info.</td>
<td>A text box for entering key words to search for relevant medline articles, rather than just choosing from the ones already there. Though the key words used by the system for searching (chief complaint, diagnosis, etc) are helpful.</td>
</tr>
<tr>
<td>Comment</td>
<td>Improvement Suggestion</td>
<td>Thoughts</td>
</tr>
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<td>---------</td>
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</tr>
<tr>
<td>I think that this tool is well organized and everything is very simple to find. I like the design of the page as well. I like that it shows relevant trials that patients might be interested in. I think that this will really help contribute to ongoing research.</td>
<td>I do like that we can narrow our search on another page, but maybe that should be on the home page instead. I also think that there should be navigation tools on the pages (like a &quot;go back to patient&quot; button) so we don't have to use the browser navigation tools.</td>
<td>See the above answer. I also don't know how helpful the word cloud is. My word cloud came up with a phone number and a couple of other useless phrases. I think that this feature is a hit or miss and I think instead there should be a search and find tool so that a doctor can search for a key word in the patient's chart instead of the word cloud.</td>
</tr>
<tr>
<td>I think the idea is cool. Work on making the information generated more specifically relevant.</td>
<td>Looking at it again, I don't like the fact that you can't hide the &quot;extras.&quot; They're distracting.</td>
<td>none</td>
</tr>
<tr>
<td>I like that all the pertinent patient information is displayed in one place on the dashboard.</td>
<td>The text in each section of the dashboard is very dense, particularly in the longer sections. The medications list is all run together. Each new med should start on a new line so that you can easily scan down the list to see what the patient is taking.</td>
<td>Need more links in the patient info sections. As far as I can tell you can't do anything except expand or collapse the different sections on the dashboard. It would be good to have links to comprehensive lab results, imaging, medications (links to info on adverse effects, contraindications, interactions etc.)</td>
</tr>
<tr>
<td>Everything is all in one place and easy to find.</td>
<td>It took a while to get the hang of the tool and figure out how to use it.</td>
<td>It may be nice to include a brief tutorial of sorts or easy help sheet to help explain how to use the tool/ get started with it</td>
</tr>
<tr>
<td>na</td>
<td>na</td>
<td>A tutorial would be nice (or did I just not find it?). I think it might need to use more specific keywords or cluster certain words in the patient emr under some general keyword that would be searched for? When I went through it, the major thing it looked for was &quot;fetal,&quot; It didn't return anything regarding HELLP syndrome or anything like that, which might give better information</td>
</tr>
<tr>
<td>The overall concept of a literature search shown adjacent to a medical record, related by some kind of word=algorithm to the record.</td>
<td>The &quot;Sex&quot; field could be changed to a click box (m/f) for ease of use. Typing out &quot;male&quot; or &quot;female&quot; is awkward. Being able to click anywhere in the result field (not just blue hyperlinked EPIC number) would increase ease of use. &quot;Patient Details&quot; organized in paragraph form, lumped together – not very easy to parse out relevant points of information. Would be better in bullet form, outline form, etc. Not sure how the &quot;keywords&quot; are proportionally weighted for literature search, but the</td>
<td>I suppose increasing the relevancy of the literature search</td>
</tr>
<tr>
<td>Easy to search patient</td>
<td>Medications list too messy to use. Should be in a list format</td>
<td>More user interface. Being able to click on the link to see the actual lab values.</td>
</tr>
</tbody>
</table>

Table 4. Free Text user comments on positives of the tool, negatives of the tool and features they wish to see in the tool.