Clinical Summarization Capabilities of Commercially-available and Internally-developed Electronic Health Records

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Summary

Objective: Clinical summarization, the process by which relevant patient information is electronically summarized and presented at the point of care, is of increasing importance given the increasing volume of clinical data in electronic health record systems (EHRs). There is a paucity of research on electronic clinical summarization, including the capabilities of currently available EHR systems.

Methods: We compared different aspects of general clinical summary screens used in twelve different EHR systems using a previously described conceptual model: AORTIS (Aggregation, Organization, Reduction, Interpretation and Synthesis).

Results: We found a wide variation in the EHRs' summarization capabilities: all systems were capable of simple aggregation and organization of limited clinical content, but only one demonstrated an ability to synthesize information from the data.

Conclusion: Improvement of the clinical summary screen functionality for currently available EHRs is necessary. Further research should identify strategies and methods for creating easy to use, well-designed clinical summary screens that aggregate, organize and reduce all pertinent patient information as well as provide clinical interpretations and synthesis as required.

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Introduction

The use of electronic health records (EHRs) has enhanced our ability to collect a large amount of patient-specific health information over long periods of time. With the impending widespread adoption of EHRs along with the creation of community and statewide Health Information Exchange systems (HIEs) [1], an immense amount of electronically available clinical data describing all aspects of a patient's care will be available to every clinician at every patient encounter. Clinicians will be responsible for reviewing and acting on all of this data [2]. However the amount of time that a clinician spends interacting with their patients on average has decreased [3–5]. Clinicians and patients already complain that a large percentage of the physician-patient encounter is now spent interacting with the EHR [3–5]. When interacting with the EHR, clinicians often need to find and interpret relevant information from various sources in a timely manner. EHR systems must therefore have powerful clinical decision support features that complement this important part of medical decision making, rather than be a hindrance to efficient patient-centered care [6].

It is now widely accepted that the adoption of an EHR will improve processes of care including documentation and retrieval of medical information, information exchange between disparate systems, and reduction of error [7]. However, barriers to EHR adoption and subsequent dissatisfaction with implemented technology still exist [8]. Studies of failure of health information technology to deliver its promises have identified the unintended consequences of its use [9]. In addition to the obvious clinical support that electronic aggregation of clinical data promises, it might add to the unintended consequences of having large amounts of longitudinal health data which may, in fact, hinder point-of-care information retrieval and decision-making. In addition, the use of structured templates that render clinical notes meaningless and difficult to read and interpret may proliferate [10]. The use of narrative unstructured text, and the complexity in navigating a multi-faceted electronic record to identify useful information can lead to subsequent information overload [9]. Many EHR systems offer some form of summary screen that provides a limited overview of an individual patient's chart. These summary screens have been found to be minimally utilized in processes of care [11]. ▶Figures 1, 2 and 3 depict examples of these summary screens.

Despite the existence of summary screens in many EHRs, there are minimal standards that determine which data elements should be included (defined nationally by the National Institutes of Standards and Technology as at least containing diagnostic test results, problem list, medication list, and medication allergy list) and how the information should be summarized [12, 13]. In particular, "Clinical Summary" Standards have been described for after-visit summaries [12] and care-transition summaries in the United Kingdom [14] but no standards exist for problem-oriented clinical summaries for healthcare providers [15]. We have developed methods for generating the knowledge required to determine, in real-time, which data elements are relevant to include in a problem oriented summary screen [16, 17]. A description of common summarization capabilities of various EHR systems provides a necessary springboard before formal evaluation and redesign that will support the cognitive needs of clinicians [18]. In order to characterize the current implementation of this type of clinical decision support, we compared the extent of the different clinical summarization capabilities of various EHR systems in use with attention to the clinical content available in general clinical summary screens.

Background

There exists a paucity of research on electronic clinical summarization, including whether or not current EHR systems have these capabilities. Summarization of medical information by clinicians has been studied under limited domains of clinical care, including handoffs [19, 20], creation of discharge summaries [21], and medical education [22, 23]. The use of automatically generated clinical summaries is promising since they could provide easy access to important data that could potentially be customized to the needs of clinicians for individualized patient care [24].

We briefly describe previous work done in electronic clinical summarization. In the neonatal intensive care setting, Law et al. in a study of forty neonatal ICU staff in 2005 discovered that textual summaries that were generated by experts lead to better choices of appropriate responses compared

to data represented as trend graphs [25]. This was later supported by a study of thirty-five neonatal ICU staff in 2008, which also discovered that human generated summary information was superior to computer generated summaries [26]. An example of a relatively widely adopted summary system is the National Health Services' Summary Clinical Record, which aggregates information about medication, allergies and adverse reactions and is intended for use in emergency and unscheduled visits. While no direct evidence of improved safety was found using this summary, Greenhalgh et al., described a small positive impact on preventing medication errors [27]. Data other than from the health record have been assessed as potentially useful sources of summary information [28], but the majority of research has concentrated on extracting data from the electronic health record and in particular, from textual data. Van Vleck et al., discovered that physicians heavily utilized textual data contained in notes whilst generating summaries [24]; Elhadad et al discovered that personalized summaries in which summaries were tailored to patient characteristics were preferred by physicians in comparison to generic summaries [29]. Afantenos et al. present a detailed evaluation of the potential of summarization technology in the medical domain, based on the examination of the state of the art, as well as of existing medical document types and summarization applications [30]. A cognitive analysis of the process of summarization performed by Reichert at al. on eight nephrologists confirmed that a large amount of time was spent in reviewing textual data, while identifying several different strategies used by physicians when summarizing relevant information. They also identify three primary goals that guided physicians in the summarization process which was to identify relevant information, validate the same with a more detailed review of data and to ascertain the current status of the problem or disease state [31].

In summary, it is clear that computer-generated clinical summaries

1. can be created in limited domains,
2. are useful and satisfying to clinicians, and
3. may improve quality and safety of care.

The only conceptual model of the process of clinical summarization was first described by Feblowitz et al. [32], who identified the need for a model that would:

1. provide a framework applicable to various types of clinical summaries
2. lay foundation to methods used to analyze clinical summaries;
3. facilitate future standardization and translation of human generated clinical summaries into electronic form; and
4. promote and extend future research on clinical summarization.

This model consists of five distinct stages – Aggregation, Organization, Reduction, Interpretation and Synthesis (AORTIS). In brief the five stages of the AORTIS model are as follows:

Stage 1: Aggregation

Aggregation is simply the collection of clinical data from various electronic sources across multiple databases or health networks, for example medication lists from the pharmacy, laboratory test results from the laboratory, progress notes from multiple providers, radiology test images from the Picture Archiving and Communications System (PACS), etc. In addition, these data may be from different parts of an integrated EHR or from multiple, community-based EHRs connected by a Health Information Exchange (HIE).

Stage 2: Organization

Organization is the arrangement of data according to some specified underlying principle without condensing, altering, or interpreting it. This sort of arrangement occurs concurrently with aggregation within the EHR unlike in a paper chart where the process is more visible and time consuming. Common organization operations are grouping (e.g. by data type or origin of service), sorting (e.g. by date or alphabetically) and prioritizing (e.g. by urgency or specialty).

Stage 3: Reduction & Transformation

Reduction is the process of filtering salient information without modifying it to decrease the amount of information presented (e.g. only displaying most recent values, values from a single location or values attributed to one provider or specialty). *Transformation* is the process of altering how the data is viewed or how the data is presented in order to facilitate understanding (e.g. graphing data over time). Another form of data reduction involves a mathematical transformation such as the calculation of descriptive statistics such as the mean, median, mode, percentile rankings, maxima, or minima, for example.

Stage 4: Interpretation

Interpretation is the context-based analysis of relevant data through the application of general clinical knowledge or rules. For example, selecting abnormal lab results to include in a patient handoff summary requires interpretation because a clinician or computer program must be able to identify which results are abnormal. In general, interpretation requires access to a clinical knowledge base and is a necessary step to produce *knowledge-rich abstracts* of clinical information.

Stage 5: Synthesis

Synthesis is the combination of two or more patient-specific clinical data elements along with general medical knowledge to yield more meaningful information or suggest action. Following knowledge-based interpretation, clinical information can be understood in relation to other parts of the medical record and can be viewed with respect to a specific patient problem.

Methods

We chose twelve different EHR systems and their general clinical summary screens for comparison. These systems were chosen based on convenience (i.e., those to which our colleagues had access), as many of the commercially available EHR systems are not publically available for comparison. A general clinical summary screen is a designated part of the EHR that displays a concise view of clinical information; such screens are usually denoted as summary screens, overview screens, or a face-sheet. For each system, we inspected screenshots of the general clinical summary screens. ▶Figures 1, 2, and 3 depict the reviewed screens for three of these systems. A complete listing of the EHR systems chosen is included in ▶Table 1.

A clinician (AL) and informatics expert (ABM) independently reviewed all the systems to determine which summary elements were included. We used Cohen's kappa to determine inter-rater agreement. For those components on which reviewers disagreed, a third reviewer (DFS) examined the screen to determine consensus.

Currently there are no standard data elements defined for such clinical summaries. A variety of clinical scenarios (inpatient versus outpatient clinical summarization needs) and different clinical user profiles (for example, nurse versus physician) may drive a variety of tasks that require the use of these clinical summaries. Hence we did not perform a formal needs analysis or narrow our examination to the summarization needs for a handful of clinical tasks. Instead, we examined each system for summarization capabilities for a variety of content types determined to be important through authors' experiences in implementation of similar summary tools (AW, DFS), informal observation and interviews of clinical summarization in ambulatory clinics using the Rapid Assessment methods described by McMullen et al. [33] and review of the literature (▶Table 2). Almost all clinical content types shown by each summary screen are included in the table. We also reviewed each screen for inclusion of other elements, such as alerts, custom reminders, diagnostics or imaging, directives, dynamic links, immunization, insurance, procedures, referrals, and task lists. We used the conceptual model described by Feblowitz et al. to frame our comparison [32].

In addition to the components of the AORTIS model, we also performed a preliminary assessment of each EHR for the different apparent aspects of the graphical user interface relevant to the

clinical summary screen. These features include specific functions of the graphical user interface that enable summarization and the display of data on the screen. The features included:

1. The ability to graph information.
2. The use of color to emphasize importance of specific information.
3. The specific layout of the user interface, including the following categories
   a) Tabbed: Use of tabbed screens to display/hide data
   b) Modular Views: The use of multiple tiled frames that allow different data elements to be seen at the same time
   c) Collapsible/Expandable screens: The use of layered frames that allow different data elements to be displayed/hidden
   d) Custom content: The ability to insert customized content on the summary screens relevant to the clinician
   e) Scrolling: The ability to scroll within the frames to display information
4. The ability to link to information within the chart
5. The ability to link to clinical reference information outside of the application

Results

Our findings are summarized in ▶Table 3. Inter-rater agreement for all summarization capabilities was moderate (kappa = 0.68). There was a wide variation in clinical summarization capabilities across the systems. Two of the studied systems catered to disease-specific populations (Open MRS – HIV/AIDS and Clinic Station – Cancer). All the systems examined seemed to aggregate, organize or reduce most of the clinical content, corresponding to the lower tiers of the AORTIS model. When reduction of clinical data was employed, more recent information was preferentially displayed.

There was only one system (NextGen) that clearly presented transformed (i.e., altering how the data is viewed or presented in order to facilitate understanding) vital signs data within the summary screen using graphs. Other systems may have other options to create graphs or other visual representations of selected data, but these were not apparent from the summary screen. Four of the studied EHR systems had the ability to interpret information (i.e., analysis of data through the application of general clinical knowledge or rules) from various clinical content – Cerner and Centricity for vital signs, where arrows are used to designate trends in temperature or pulse rate, and Spring Charts and LMR for health care maintenance reminders, which were specified based on patient information. Only one system (LMR) combined information to synthesize recommendations for further action on the summary screen (for example, aspirin for coronary artery disease equivalent disease, diabetes mellitus present on problem list; and age more than 65, requiring pneumococcal vaccination).

Two systems, LMR and Star Panel, had data fields contextually linked to specific data within the chart as well as specific reference information. Three of the studied EHR systems (LMR, NextGen and Clinic Station) allowed clinicians to customize the clinical content that was presented to them, but only one system (LMR) allowed the presented data to be edited directly from the clinical summary screen. Scrolling and tabbed screens were used commonly to display information that did not fit into the default size of the screen. Most systems attempted the display of the summary information using modular views (boxes or windows) to separate the content displayed

Discussion

The Institute of Medicine's recent report on "Health Information Technology and Patient Safety: Building Safer Systems for Better Care" correctly recognized that many EHR vendors restrict access to screenshots of their products [34]. If we are to collectively develop the next generation of safe and effective EHRs, we must have the ability to review, compare, and comment on the features and functions of all EHRs. Therefore, our findings, while not an exhaustive analysis of all currently available EHR systems, suggest that, while most of the EHR systems studied have some similarities, they vary widely not only in the content and presentation of information but also in the ability and extent of summarization that may support clinical decision making. Our results emphasize that the electronic

clinical summary screens often lack customizability and have only a limited ability to extract contextually linked specific patient information. They commonly use less sophisticated techniques in the process of clinical summarization like aggregation and organization rather than more active clinical decision support that is provided by the interpretation of information using clinical rules and the synthesis of recommendations for further action. Our study is limited by its observational nature and by the inability to directly interact with systems capabilities; but since a general clinical summary screen is inherently a clinical "snapshot", our study in fact highlights the aspects of the summary screens that are vague and not easily discoverable from the interface. An obvious next step in our research would be a detailed interactive usability comparison for each screen.

Clinicians are often presented with large amounts of aggregate data from a variety of sources both in paper and electronic form and have to process this information in a manner that is not only conducive to medical decision-making but is also transparent in other subsequent processes of care, for example communication of relevant information while referring a patient to a colleague. Inadequate attention to the clinical summarization process can lead to various potential failures due to information that has been overlooked, including missed allergy information, inadvertent medication errors, and missed or delayed diagnoses, all leading to adverse patient outcomes [35]. From a user's perspective this could lead to potential information overload, dissatisfaction with the electronic health record and subsequent adoption of unsafe workarounds and resistance to the adoption of otherwise potentially useful technology [36–38]. Therefore, the way that relevant information is summarized and presented to the clinician in an EHR is of increasing importance. Each component in the AORTIS model has significant safety implications; thus the authors recommend that EHRs should strive to adopt each in its summary screen. The higher levels of this model (i.e., transformation, interpretation and synthesis) are superior methods for displaying pertinent information, but the components chosen to display data should be tailored to the information needs of the clinician. In particular, we encourage EHR designers and developers to include more graphical, transformation-type elements (e.g., SparkLines) in their summary screens [39].

The authors also recommend that vendors openly participate in collaborative research, working together with informaticians, clinicians and patient safety researchers in order to create safe and relevant clinical summary screens. The planned next steps in our study include a more formal naturalistic observation and artifact analysis to supplement our understanding about the nature and context of use of these clinical summary screens. We are also currently exploring the development of clinical knowledge bases that would allow clinical summary screen developers to organize a patient's data by clinical condition. In other words, the clinician would be able to review all of a patient's medications that were being used to treat a particular condition along with relevant laboratory test results required to monitor either the condition or its treatment.

Conclusion

Improvement of the clinical summary screen functionality for currently available EHRs is necessary. It is imperative that EHR developers create new standard clinical summarization features, functions, and displays if clinicians are to achieve the anticipated benefits of state of the art EHRs. Further research should identify strategies and methods for creating easy to use, well-designed clinical summary screens that aggregate, organize and reduce all pertinent patient information as well as provide clinical interpretations and synthesis as required.

Conflicts of Interest

The authors declare that they have no conflicts of interest in the research.

Ethics

No human subjects were involved in the study.

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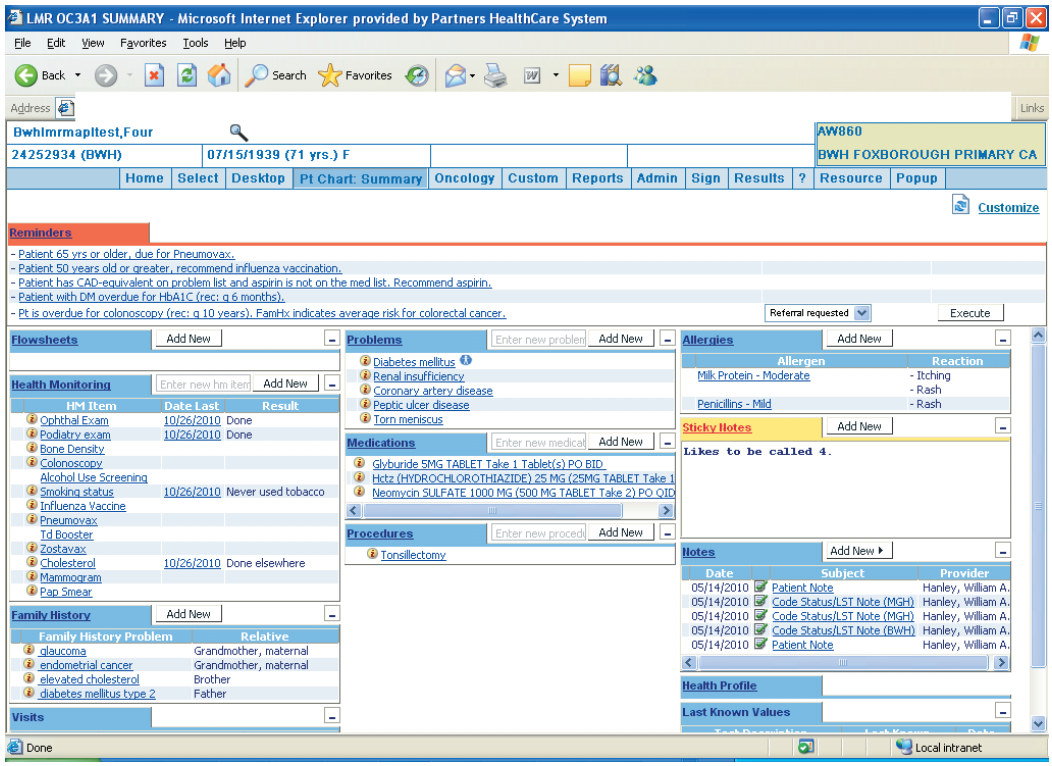

Fig. 1 Screen print of Partners HealthCare System's Longitudinal Medical Record (LMR) clinical summary screen

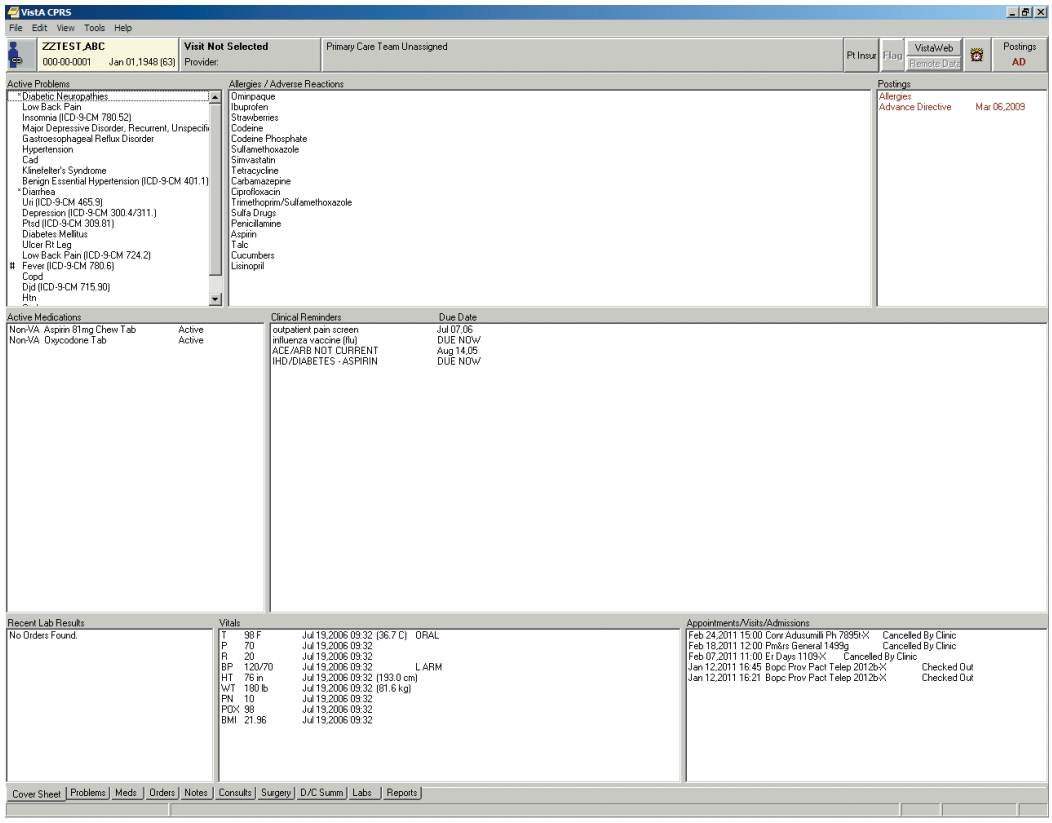

Fig. 2 Screen print of the Veterans Affairs Health System's Computerized Patient Record System (CPRS) clinical summary screen

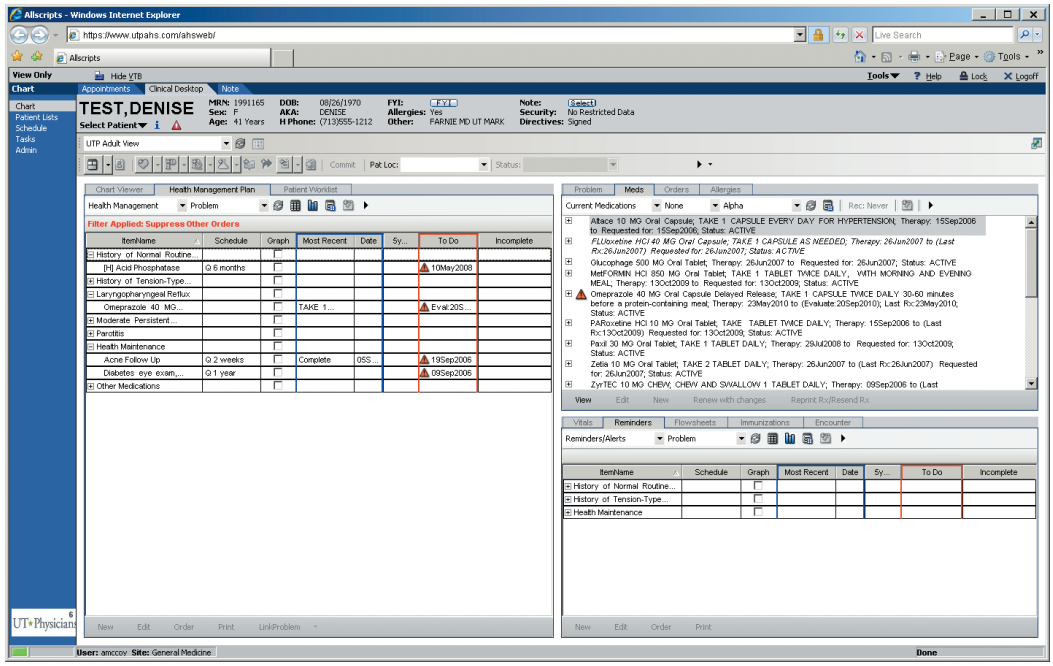

Fig. 3 Screen print of the UTHealth Practice Plan's Allscripts clinical summary screen

Table 1 Examined clinical summary screens

EHR Product	Version	Implementation Site (blinded for peer review)	Type of system
Partner's LMR	Fall 2010	Partners Healthcare System, MA	Locally developed
Allscripts Enterprise	v11.2.0	UTHealth Practice Plan, TX	Commercially available
CPRS	v1.0.27.90	VA Houston, TX	Freely available
GE Centricity	2008 version	University of Medicine & Dentistry, NJ	Commercially available
OCW	v1.9.802	Oschner Clinic, LA	Locally developed
StarPanel	N/A	Vanderbilt Practice Plan, TN	Locally developed
Springcharts	v1.6.0_20	Web Demo	Commercially available
OpenMRS	v1.7.1	Web Demo	Open Source; Freely available; Disease-specific (HIV/AIDS)
Cerner	v2010.01	Stonybrook, NY	Commercially available
ClinicStation	v3.7.1	MD Anderson, TX	Locally developed; Disease-specific (Cancer)
NextGen	Early 2008 version	Mid-Valley Independent Physician's Association, OR	Commercially available
Epic	v 2009 IU7	Harris County Hospital District	Commercially available

LMR- Longitudinal Medical Record; CPRS-Computerized Patient Record System; OCW- Oschner Clinical Work Station; MRS – Medical Record System.

Table 2 Content types evaluated for inclusion in summary screens

Content Type	Example
Vitals	Current and past temperature, blood pressure, pulse, respiratory rate
Medications	Previously or actively prescribed medications
Visit Schedule	Past, current, or future scheduled appointments
Patient Information	Current patient demographics, picture, or other identifying information
Allergies	Medication allergies documented for the patient
Problem List	Previous or active clinical problems, diagnoses, or medical conditions
Health Care Maintenance	Reminders for vaccinations or cancer screening
Labs	Recent clinical laboratory test results

Table 3 Clinical summarization capabilities of the examined electronic health record systems

Characteristic		EHR Vendor											
		CPRS	AllScripts	Next Gen	LMR	OCW	Centricity	Clinic Station	Star Panel	Spring Charts	Cerner	Open MRS	Epic
Content	Vitals	A O R	A O	A O T	Absent	Absent	A O I	A O	A O	Absent	A O R	Absent	Absent
	Medications	A O R	A O R	A O R	A O R	A	A O R I	A O	A O	A O R	A O	A R	A R
	Visit Schedule	A O R	A O	A O	A O	Absent	Absent	A O	Absent	Absent	A O	Absent	Absent
	Patient Information	A O R	A O R	A O R	A O R	A O R	A O R	A O R	A R	A O	A O	A	A O R
	Allergies	A	A O	A	A O	A	A	A O	Absent	A	A O	A	A
	Problem List	A R	A O R	A	A O R	A	A R	A	A O R	A O R	A O R	A R	A
	Health Care Mainten-ance	R	A	Absent	A O I	Absent	Absent	Absent	A O	A O R	A O	A O R I	A O R I
	Labs	A O R	A O	AO	Absent	Absent	A O	A O	Absent	Absent	A O R	Absent	Absent
	Other Con-tent	Directives	Custom Rem-inders; Diagnostics/Im-aging; Immunization; Procedures		Custom Reminders; Dynamic Links; Immuni-zation; Procedures	Alerts; Insurance; Task List	Directives; Insurance; Procedures	Diagnostics/ Imaging; Directives; Dynamic Links	Alerts	Referrals	Custom Reminders; Diagnostics/ Imaging; Immuni-zation; Procedures	Custom Reminders; Insurance; Procedures; Referrals	Custom Reminders

Table 3 Continued

Characteristic		EHR Vendor											
		CPRS	AllScripts	Next Gen	LMR	OCW	Centricity	Clinic Station	Star Panel	Spring Charts	Cerner	Open MRS	Epic
Struc-ture	Graph	Absent	Absent	Present	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent
	Color-Emphasis	Present	Present	Absent	Present	Absent	Present	Absent	Present	Present	Present	Absent	Absent
	Custom Layout	MV; Sc	Tb; CoE; Sc	MV; Cu; Sc	MV; CoE; Cu; Sc	MV; Sc	MV; Sc	Tb; CoE; Cu; Sc	Tb; MV; Sc	MV; Sc	Tb; MV; CoE; Sc	MV	MV
	Chart Specific Information	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present
	Reference Information	Absent	Absent	Absent	Present	Absent	Absent	Absent	Present	Absent	Absent	Absent	Absent

A-Aggregation; O-Organization; R-Reduction; T-Transformation; I-Interpretation; S-Synthesis; Tb-Tabbed; MV-Modular Views; CoE-Collapsible/Expandable; Cu-Custom content; Sc- Scroll

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