Graphical display of diagnostic test results in electronic health Records: a comparison of 8 systems

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ABSTRACT

Accurate display and interpretation of clinical laboratory test results is essential for safe and effective diagnosis and treatment. In an attempt to ascertain how well current electronic health records (EHRs) facilitated these processes, we evaluated the graphical displays of laboratory test results in eight EHRs using objective criteria for optimal graphs based on literature and expert opinion. None of the EHRs met all 11 criteria; the magnitude of deficiency ranged from one EHR meeting 10 of 11 criteria to three EHRs meeting only 5 of 11 criteria. One criterion (i.e., the EHR has a graph with *y*-axis labels that display both the name of the measured variable and the units of measure) was absent from all EHRs. One EHR system graphed results in reverse chronological order. One EHR system plotted data collected at unequally-spaced points in time using equally-spaced data points, which had the effect of erroneously depicting the visual slope perception between data points. This deficiency could have a significant, negative impact on patient safety. Only two EHR systems allowed users to see, hover-over, or click on a data point to see the precise values of the *x*–*y* coordinates. Our study suggests that many current EHR-generated graphs do not meet evidence-based criteria aimed at improving laboratory data comprehension.

Keywords: diagnostic tests, user computer interface, electronic health records, national health policy

BRIEF COMMUNICATION

INTRODUCTION

Recently, two Senators proposed the Medical Electronic Data Technology Enhancement for Consumers' Health Act exempting regulation of electronic health records (EHRs) and selected clinical decision support features from Section 520 of the Federal Food, Drug, and Cosmetic Act. Among specific aspects of EHRs that they propose to exclude is software solely for administrative, operational, or financial record processing. In addition they specifically propose to exclude software "intended to format, organize, or otherwise present clinical laboratory test report data prior to analysis, or to otherwise organize and present clinical laboratory test report findings or data"[1] from oversight. The intent of this bill, which was introduced but not enacted in the 113th Congress, was to limit the US Food and Drug Administration's control over EHRs.

As part of an Agency for Healthcare Research and Quality-funded research project focused on management of abnormal laboratory test results, we reviewed how EHRs displayed laboratory results graphically. During preliminary demonstrations of three EHRs, we identified several areas of concern that warranted further evaluation. In an attempt to ascertain whether this was a problem across EHRs, we evaluated the graphical displays of laboratory test results in five additional EHRs to assess their effectiveness to communicate information clearly and accurately.

METHODS

We evaluated graphical displays of chronological, numerically-reported, laboratory test results in eight current EHR user interfaces: six EHRs were certified by the Office of the National Coordinator for Health Information Technology authorized testing and certification bodies,[2] one a prototype EHR, and one the Veterans Affairs Computerized Patient Record System[3] (see Table 1). Selection was based on convenience sampling and facilitated by our efforts to reach out to our collaborators who would agree to give us a HIPAA-compliant demonstration of their EHR. We also reviewed several freely available online videos that showed demonstrations of various EHR's functionality. In sample selection, we attempted to identify and test as many of the leading, commercially-available EHRs as possible. We developed, and used for comparison, 11 objective criteria for optimal graphs based on literature[4,5] and expert input (see Table 2 and Figure 1). All of the criteria aimed to ensure conformity with widely accepted principles of good data presentation.

RESULTS

Our evaluation revealed that none of the EHR graphs we studied met all 11 evaluation criteria (see Table 3). The magnitude of deficiency ranged from one EHR meeting 10 of 11 criteria to three EHRs meeting only 5 of 11. No EHR had a graph with *y*-axis labels that displayed both the name

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Table 1: Electronic health records reviewed

Allscripts Enterprise v10	Glassomics v1
Cerner Millennium Powerchart 2012	Meditech v5.64
eClinicalWorks v10	Partners Longitudinal Medical Record v9.3
Epic Hyperspace v2012	VA Computerized Patient Record System v2014

Table 2: Overview of the criteria used to evaluate the EHR's graphical displays

Patient ID visible	The patient's name, birthdate, and gender are clearly displayed on the graph, or on the display frame that incorporates the graph and cannot be obscured while viewing the graph.
Title	A description of graph's contents, including the observed variable(s), is clearly displayed on the graph.
***x*-axis label**	A description of the meaning of the *x*-axis' content is clearly displayed. The label "Date" or "Time" can be assumed if *x*-axis tick marks are clearly labeled with dates (2 February 2015) or time stamps (11:00 a.m.).
***x*-axis scale**	The *x*-axis has multiple, intermediate, evenly-spaced tick marks.[8]
***x*-axis values**	The *x*-axis has labels that clearly indicate the numerical value of tick marks. The *x*-axis tick mark labels should increase in value as they move from left to right along the axis.
***y*-axis label**	A label on the *y*-axis clearly states the name of the variable and its units (e.g., Systolic Blood Pressure [mm Hg]).
***y*-axis scale**	The *y*-axis has multiple, intermediate, evenly-spaced tick marks.
***y*-axis values**	The *y*-axis has labels that clearly indicate the numerical value of tick marks. The *y*-axis tick mark labels should increase in value as they move from the bottom to the top of the graph.
Legend	If there are two or more observed variables plotted on the graph, there should be a legend explaining the different colors or shapes used to mark the data points.
Reference range	The reference range is shown for each observed variable.
Data details	Precise *x*–*y* data point values are available (e.g., user can view, hover over with the mouse, or click to see more details) for each data point graphed.

Figure 1: A stylized graph used to illustrate the criteria we developed and used to evaluate the various EHRs.

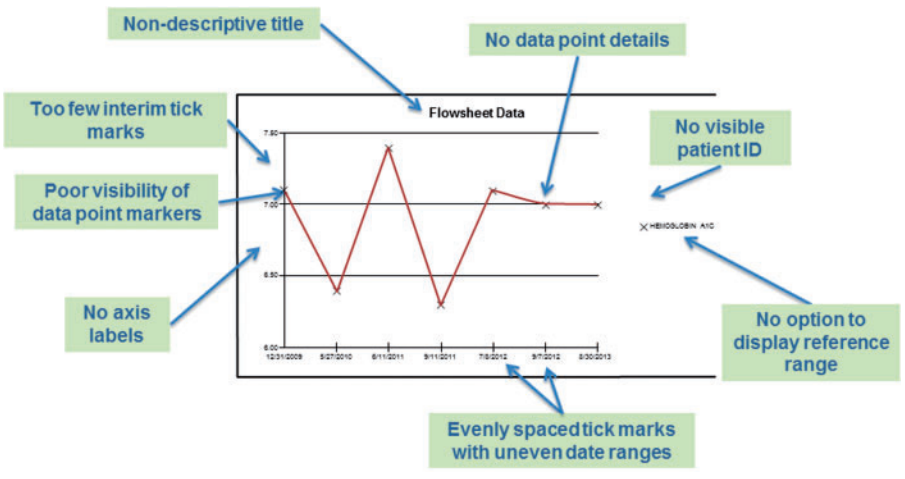


Table 3: Comparison of eight EHRs graphing capabilities

System → Criteria	EHR A	EHR B	EHR C	EHR D	EHR E	EHR F	EHR G	EHR H
Patient ID visible: name/birthdate/gender	Yes	Yes	**No** (Name only)	Yes	Yes	Yes	Yes	Yes
Title: description of graph's contents, incl. observed variable(s)	Yes	Yes	Yes	**No**	Yes	**No**	Yes	Yes
***x*-axis label:** state meaning of the data and units	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
***x*-axis scale:** Evenly-spaced intermediate tick marks	Yes	Yes	Yes	**No** (even space, unequal time)	**No**	**No**	**No**	**No** (reverse Chron order)
***x*-axis values:** labels indicating numerical value of tick marks	Yes	Yes	Yes	Yes	Yes	**No**	Yes	**No (end pts only)**
***y*-axis label:** state meaning of the data and units	**No** (units only)	**No**	**No**	**No**	**No**	**No** (no units)	**No**	**No** (units only)
***y*-axis scale:** Evenly-spaced intermediate tick marks	Yes	Yes	Yes	Yes	**No**	Yes	**No**	**No**
***y*-axis values:** labels indicating numerical value of tick mark	Yes	Yes	Yes	Yes	Yes	Yes	**No**	**No**
Legend: if >1 observed variable	Yes	Yes	**No**	Yes	Yes	**No**	Yes	**No**
Reference range(s): shown for observed variable	Yes	**No**	Yes	**No**	**No**	Yes	**No**	Yes
Data details: Precise x-y data point values	Yes	**No**	**No**	**No**	**No**	**No**	**No**	Yes

(Note: gray cells indicate nonadherence to best practices)

Figure 2. A screen shot from the Veteran's Affairs Computerized Patient Record System showing a graph of a patient's hemoglobin A1c levels over time.

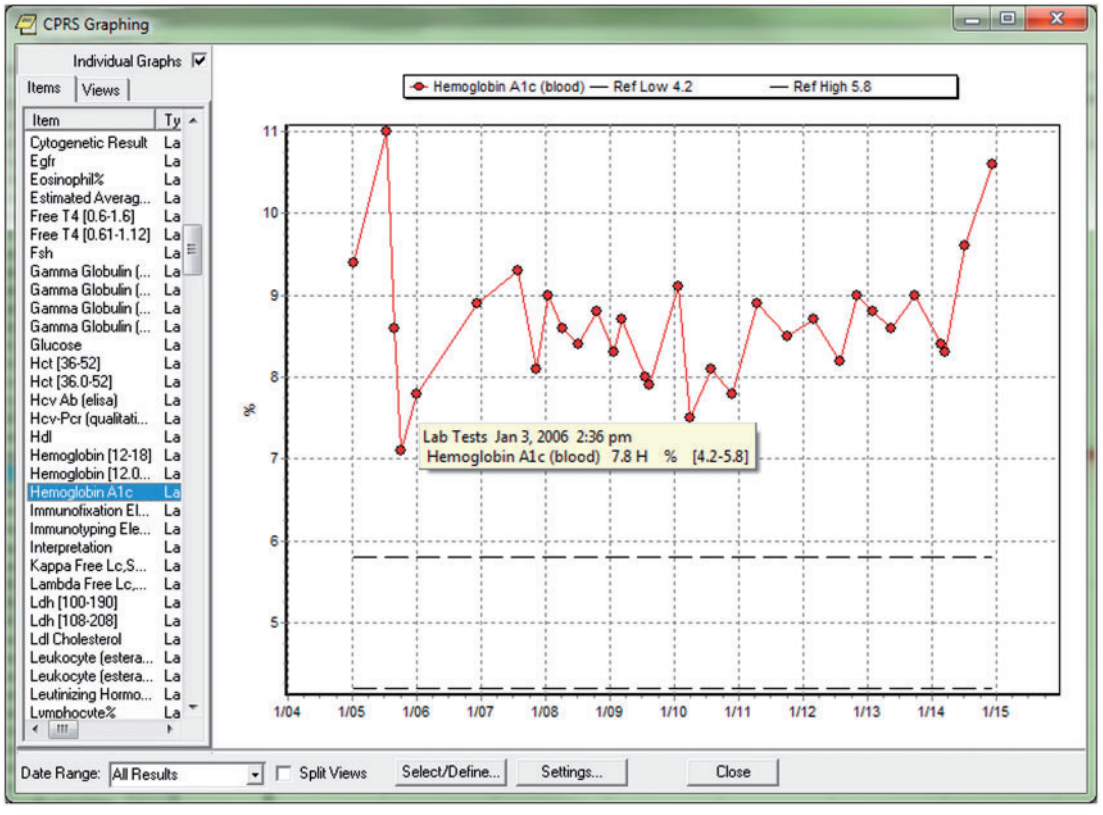
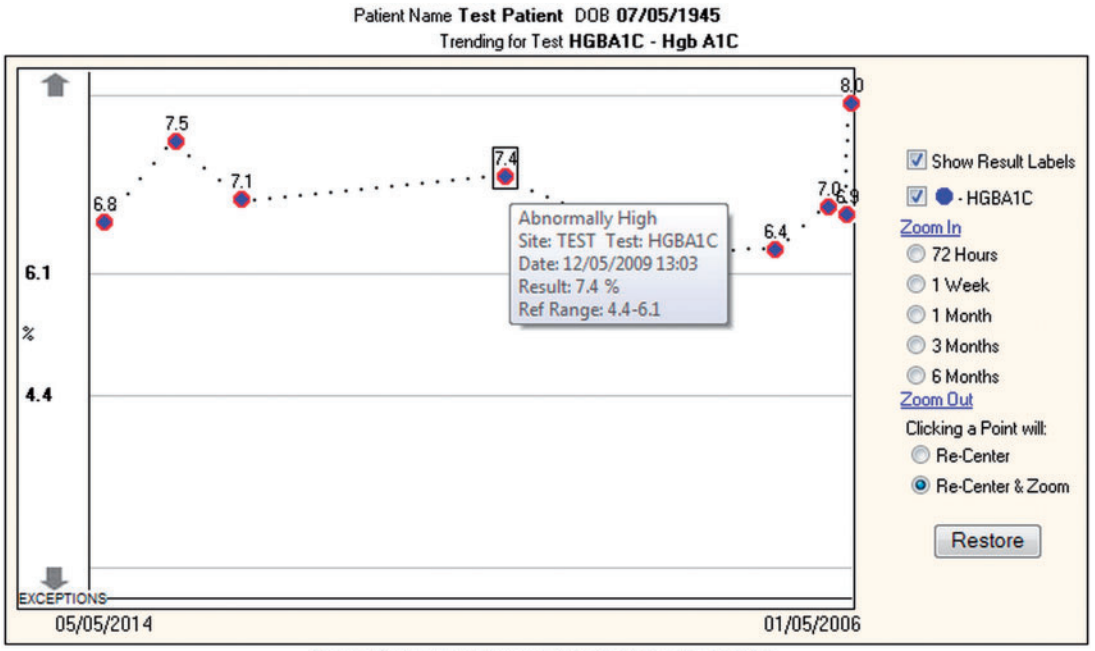


Figure 3: A screen shot from Partners Healthcare System's Office of the National Coordinator for Health Information Technology authorized testing and certification bodies certified Longitudinal Medical Record system. Note that the *x*-axis displays results in reverse chronological order.



of the measured variable and the units of measure; although two systems displayed the units of the measured variable and one displayed the name of the measured variable. One EHR system graphed results in reverse chronological order (i.e., the most recent results on the left side of the graph). One EHR system plotted data collected at unequally-spaced points in time using equally-spaced data points, which had the effect of erroneously depicting the visual slope perception between data points. This deficiency could have a significant, negative impact on patient safety. Only two EHR systems allowed users to see, hover-over, or click on a data point to see the precise values of the *x*–*y* coordinates (see Figures 2 and 3). Three EHRs did not display the patient's ID directly on the graph, although patient ID information was available in the display frame incorporating the graph. This issue could pose a problem if a) the user is able to print the graph and that printout does not include the patient ID or b) the user expands or moves the graph window so that it occludes the patient ID information.

DISCUSSION

Many current commercial EHRs have significant limitations in graphing capabilities of laboratory test results and often display results in nonstandardized fashion. Accurate display and interpretation of clinical laboratory test results is essential for patient safety. EHR-generated graphs often provide important diagnostic clues, such as downward hemoglobin trends with gastrointestinal bleeding, increasing creatinine levels with renal failure on nonsteroidals, or rising prostate specific antigen levels suggestive of prostatic disease. Additionally, EHRs using reverse chronological order graphs could be particularly confusing to users.

With wider implementation of EHRs, more clinicians will rely on automatically-generated computerized displays that allow clear and accurate visual synthesis of data over time.[6] Suboptimal displays could have serious implications for clinical decision-making. This is relevant because the April 2014 Food and Drug Administration Safety and Innovation Act report[7] proposed that "no new or additional areas of FDA oversight [of EHRs] are needed." Further, the report stated that the FDA does not intend to oversee products with health management IT functionality that qualify as medical devices according to the statutory definition (i.e., "an instrument, apparatus, implement, machine, contrivance, implant, *in vitro* reagent, or other similar or related article, including any component, part, or accessory, which is . . . intended for use in the diagnosis of disease or other conditions, or in the cure, mitigation, treatment, or prevention of disease, in man or other animals").

We recommend policymakers ensure clear and accurate visual display of laboratory data through more stringent Office of the National Coordinator for Health Information Technology authorized testing and certification bodies EHR certification testing criteria. These criteria should be based on the best available scientific evidence from the literature and expert opinion, when no published evidence exists. Our study also underscores the need to inform frontline providers, who might depend on graphs in their day-to-day clinical decision-making, to be careful to review the basic components of their EHRs' graphs to ensure they understand exactly what each data point represents.

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COMPETING INTERESTS

None.

CONTRIBUTORS

All authors made substantial contributions to the design of the study. All authors participated in the acquisition, analysis, and interpretation of the data. D.F.S. wrote the first version of the manuscript. All other authors helped revise it critically for important intellectual content. All authors approved the final version of the manuscript and are accountable for the work.

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