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Designing a Medication Timeline for Patients and Physicians

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ABSTRACT

Objective

Most electronic health records display historical medication information only in a data table or clinician notes. We designed a medication timeline visualization intended to improve ease of use, speed, and accuracy in the ambulatory care of chronic disease.

Materials and Methods

We identified information needs for understanding a patient medication history, then applied human factors and interaction design principles to support that process. After research and analysis of existing medication lists and timelines to guide initial requirements, we hosted design workshops with multidisciplinary stakeholders to expand on our initial concepts. Subsequent core team meetings used an iterative user-centered design approach to refine our prototype. Finally, a small pilot evaluation of the design was conducted with practicing physicians.

Results

We propose an open source online prototype that incorporates user feedback from

initial design workshops, and broad multidisciplinary audience feedback. We describe the applicable design principles associated with each of the prototype's key features. A pilot evaluation of the design showed improved physician performance in five common medication-related tasks, compared to tabular presentation of the same information.

Discussion

There is industry interest in developing medication timelines based on the example prototype concepts. An open, standards-based technology platform could enable developers to create a medication timeline that could be deployable across any compatible health IT application.

Conclusion

The design goal was to improve physician understanding of a patient's complex medication history, using a medication timeline visualization. Such a design could reduce temporal and cognitive load on physicians for improved and safer care.

BACKGROUND AND SIGNIFICANCE

In the US, physicians are seeking ways to improve the safety of their Electronic Health Records (EHRs), and to reduce the time, effort, and cognitive load while using them in the face of an aging population with an increasingly complex chronic disease burden.[1] Physicians are facing increasing levels of burnout, partially due to dissatisfaction with the workload and lack of usability associated with using their EHRs.[2],[3]

Ambulatory patients with chronic disease typically have multiple morbidities and may take many medications. One study of adults with chronic disease found the mean number of medications was 6.3, and 10% of patients took more than 12 medications.[4] A few can have up to 30 (author's experience). Longer medication lists are more complex to read, and it is more difficult to perceive the historical treatment course. In primary care practices, there are unmet needs for reducing cognitive load and improving efficiency using the EHR.[5],[6] Making treatment decisions without the full array of necessary clinical patient information increases the risk of medication errors.[7]

Improved data visualization can help to improve clinician speed and accuracy of ascertaining clinical information. Our team at University of Missouri School of Medicine compared use of a diabetes dashboard screen deployed within the EHR with a conventional approach of viewing multiple EHR screens to find data needed for ambulatory diabetes care. Physician users were faster with the dashboard data visualization (mean time 1.3 vs 5.5 minutes; p <.001) and correctly found more of the data requested (100% vs 94%; p <.01). Far fewer clicks were needed using the dashboard (3 vs 60 clicks; p <.001).[8]

Researchers at the Regenstrief Institute created a decision support system designed to expedite reviewing potential adverse reactions through information visualization. The system generates maps for adverse reaction for any user-selected combination of drugs, incorporating a numeric score reflecting the strength of association between the drug and adverse reaction pair. They compared speed and accuracy using this tool to complete a query to retrieve side-effect data versus UpToDate®. The tool was 60% faster (61 seconds vs. 155 seconds, $p < 0.0001$) with no decrease in accuracy.[9] Researchers at University of Utah College of Nursing compared data interpretation performance by critical care nurses and nursing students when arterial blood gas results were presented in a traditional numerical list versus a graphical visualization tool. Average accuracy using the traditional method was 69% and 74% for critical care nurses and nursing students, respectively, compared to 83% and 93% with the visualization tool.[10] By enhancing clinician decision-making, improved visualization has the potential to advance the quality of clinical care.

OBJECTIVE

The Office of the National Coordinator of Health IT (ONC) has funded research and dissemination efforts addressing the adoption of EHR technology, and of improving its usability and safety.[11] In the scope of the ONC emphasis on safety-enhanced EHR design, our team, funded jointly by the SHARP-C project of the ONC and by the California HealthCare Foundation, addressed the domain of safety and usability of the individual patient medication list, particularly the longitudinal historical view of the medication list. In this report, we focus on the development of the medication timeline to satisfy physician needs for this user story: “As a provider of ambulatory care for chronic diseases, I need to review a patient’s past patterns of medication use and reasons for changes in order to make safe and effective treatment decisions.”

ITERATIVE DESIGN PROCESS

Materials and Methods

Our overall approach to participatory design was inspired by the design study methodology described by Sedlmair.[12] “We define a design study as a project in which visualization researchers analyze a specific real-world problem faced by domain experts, design a visualization system that supports solving this problem, validate the design, and reflect about lessons learned in order to refine visualization design guidelines.“ We identified physician and patient/caregiver information needs for comprehending historical medication use patterns (“What happened before?”) while managing chronic disease in the ambulatory setting for an individual patient with multiple morbidities and multiple medications. Common information needs include needing to know all medications used currently, when and why dose changes occurred, and how changes related to one another (e.g. starting one drug because another was stopped). There is also a need to make cross-categorical comparisons with other health data including blood pressure, weight, and pertinent lab results. A timeline visualization is not suitable for all clinical tasks, and completely different tasks performed by physician or patient/caregivers might require alternative information displays. For instance, compared to mere review of a medication list, prescribing activities require the additional knowledge of medication quantity, number of refills, remaining time available on the previous prescription, identification of the prescriber, the selected pharmacy, identification of potential interactions, and formulary coverage details.

Identifying user needs

From primary care physician members of our team, we identified key user needs in reviewing and understanding complex medication histories when caring for a patient with complex chronic diseases. Physicians (and other prescribing provider users) need the following information: medication names, strength, average total daily dose, dosing instructions, start-stop dates for any dose change, reasons for making those changes, quick comparison with other concurrent drugs, and comparison to related lab results and vital signs (blood pressure and weight) that affect or can be affected by the medication in question. These data allow physicians to accomplish the kinds of tasks listed in Table 1.

Table 1. Medication history review tasks for care of chronic disease

Task	EHR current state
Identifying current prescription on a medication history	Easy
Identifying past prescriptions on a medication history	Can be done with one or more steps currently
Identifying the length of time a medication has been prescribed	Difficult in list view; can be searched in some EHRs
Identifying new prescriptions in a given time interval	Cumbersome
Identifying a dosage change in a given time interval	Cumbersome
Making intercategorical comparisons of medication changes with other data categories (blood pressure, weight, lab results)	Available in only one EHR in mobile (tablet) product

In 2012 and 2013, we reviewed 12 EHR products in general release ranging from large to small at the annual international HIMSS conference trade show floor, assessing the capability for displaying multiple years of medication history in a single screen and for making cross-categorical temporal connections of data. We asked each vendor to display a medication timeline view (if they had one) and the table view of the medication list that could show past medications. None allowed a historical overview of all medications in a single view or information display. None used graphical data visualization features.

In many EHRs these information needs are currently addressable only by scouring the content of past physician notes, or by digging through tabular views of many rows of medications past and present (filterable to hide or reveal medications no longer actively used by the patient). These puzzle pieces of information are scattered among different areas of the EHR, making these existing methods time-consuming, frustrating, and error-prone. They can strain working memory by separating content within a page or between pages, which can cause a heavy cognitive load when making comparisons with interrelated data (i.e., prescriptions, dosage, and dates) and associated data (such as lab results and weight). Time-consuming tasks may produce no results because they can be unsuccessful, aborted, or not even attempted due to difficulties with collecting the data for decision making.

Reviewing History of Timelines

Graphical timelines are well suited to this set of user needs. One of the earliest timelines in print was Joseph Priestley's timeline display of "A New Chart of History" in 1769, listing events in 106 separate locations.[13] In the 1980's, data visualization enjoyed an increase in popularity. In the 90's, different ways of visualizing medical information were introduced, including the timeline, the most popular of which being LifeLines.[14,15] LifeLines incorporated a large variety of medical information into an interactive display with several novel features including 1) a personal history overview on a single screen, 2) direct access to all detailed information from the overview with one or two clicks of the mouse, and 3) critical information or alerts visible at the overview level. Since then, visualization technologies have incorporated many new features, but the medication timeline using multiple bars has been seemingly unchanged.

Data visualization techniques have evolved over the past few decades with the user in mind. Visualization techniques reduce cognitive computation and reduce the amount of information needed to be searched before drawing conclusions,[16] and medical experts prefer graphical representations over data tables when searching for trends.[17] Early techniques incorporated methods to denote specific events, using various symbols to denote simple and complex events, intervals of time, and overlapping events.[18] Others utilized such techniques for medical information timelines to emphasize the most recent data while maintaining a visual history of the data.[19]

Several designs were introduced in the early 2000's using Shneiderman's "overview first, zoom and filter, then details on demand" mantra.[20] Another popular feature was the colored bar to denote extended events, initially introduced as a feature of Patient History in Pocket (PHiP), a medical history visualization software.[21] A more recent software development, Medical Information Visual Assistant (MIVA), allows users to customize their experience with drag and drop menus to highlight the features they are interested in viewing.[22]

LifeLines is interactive, displaying only the medication start dates on the broad overview (Figure 1A), but continuous colored bar graphs upon zooming for details, with dispensing events and expected duration of the medication prescription (Figure 1B)[14]. Alonso et al evaluated Lifelines in a juvenile justice setting, comparing timeline view to tabular view for responding to 31 detailed questions regarding youths' personal history with the juvenile system. The timeline excelled for interval comparisons and making intercategorical connections, while the tabular view excelled at finding exact dates.[23]

(Insert Figure 1A & 1B)

Iterating the Baseline Timeline Model

The LifeLines model has several features that supported our design aims. These include an overview of all medications in a single view for any time interval; high information density; rapid visual comparisons using pre-attentive attributes (color, size, shape, orientation, motion); and the ability to display multiple medication variables at once: duration (length), daily dose amount (color and intensity), doses per day (symbol encoding), and incomplete adherence (gaps in line). The medication timeline concept is well adapted to displaying associated data (lab results, vital signs such as blood pressure and weight, and key incidents such as hospitalization or surgical procedures) in adjacent timeline or graphical views or added as annotations. The LifeLines concept has been incorporated into several operational systems.[24]

Belden has created various pencil sketch versions as early as 2010 exploring alternative design patterns with high information density incorporating height to represent dosage strength (Figure 2A), color, line weight and line style (single, double, triple, dashed, etc.) to represent daily dosing instructions. These sketches explored alternative display methods for renewal and dispensing events and adherence gaps. Pencil sketches allow rapid iteration at low cost and embrace frequent failure as a strategy for succeeding sooner.[25] For example, early on, we opted in favor of using a fixed height bar with color distinctions to represent dosage as opposed to using variable height bars to convey medication dosage. Using variable height for dosage required more vertical space than uniform width bars. Using fixed height bars could employ black as a maximum dose (black is readily recognized as “maximum gray”), whereas a maximum height was not readily discernable. Recognizing dosage maximum quickly helps to prompt physicians to add an additional medication.

(Insert Figure 2)

Engagement of Stakeholder Workshop Members

This medication timeline prototype effort was part of a larger 5-domain effort for a clinically inspired design guide for EHR vendors. To seek engagement from the EHR vendor community, we met with the Electronic Health Records Association Clinician Experience Workgroup to assure that our effort would address their commercial needs to improve the clinician experience. We engaged ten health IT vendor workshop participants with product development experience representing both large and small health IT organizations, distributed over 3 on-site workshops. Participant breakout group design sketches and design requirements were subject to design critiques and multi-voting to develop consensus. We held a kickoff workshop with our vendor participants, and subsequent weekly calls with the core author team, with more frequent iteration between the professional design team and the project leader. Starting with preliminary design concepts, this team expanded the design, explored alternatives, and specified detailed sketches and feature lists for a working medication timeline prototype intended to be open-source for HIT developers to use and adapt. We modernized the look of LifeLines with inspiration from the design language of the flight search tool, Hipmunk.com[26]. Given our budget and time constraints, we prioritized a set of minimal features for our interactive timeline prototype and rendered the backlog content as supplemental static illustrations of additional feature designs.

Advisory Panel

We convened an Advisory Panel of 12 subject matter experts in human factors, pharmacology, medicine, and nursing to solicit their critical review and user feedback, incorporating the feedback into iterative design revisions. This feedback was collected using a combination of written submissions, a survey with a small number of respondents (5), and two group conference calls with written field notes. The conference call moderator asked the participants to address the overall e-book product and respond to a series of prompts about the content and the design framework. The medication timeline was among several content topics. There was unanimous consensus among the vendor and advisory panel clinician participants about the content of the medication timeline display.

Results

Using an iterative design process, our team arrived at a final prototype (Figure 3), available online at inspiredEHRs.org/timeline[27]. The features are detailed in Table 2, along with the associated principles that support the design.

(Insert Figure 3)

Table 2. Features of interactive medication timeline and their associated human factors and design principles

Number	Feature	Principles & Rationale
1	Display overview of all medications for selected time in a single screen without scrolling.	• Achieve spatial contiguity and reduce demands on working memory.[28] • Allow quick visual queries.[29] • High information density for complex patients.
2	Default interval is 2 years.	During ambulatory care visits for chronic disease, providers need >12-month history.
3	Medication names display on both left and right side of the view area, making it easier to identify the name for an associated row.	Gestalt principles of proximity and alignment.[30]
4	Right-hand drug name panel also serves as the time scrubber, dynamically updating drug & dose as the user moves the scrubber.	System shows state dynamically.[29]

5	Use monochrome grayscale bar graph, where black represents maximum daily dose for a given clinical indication (diagnosis). Gray is less, lighter is lower.	Intensity corresponds to dosage strength.
6	Longitudinal bar graphs display start-stop-change dates, dose intensity, and gaps in continuity.	Pre-attentive attributes (color, shape, length) allow rapid visual processing of medication dosing and duration.[31]
7	Change the displayed time interval (zoom in or out) with range selector.	Overview first, zoom & filter, then details on demand.[32]

Harkening to the data visualization mantra of Shneiderman of “overview first, zoom and filter, then details on demand,” we wanted to harness the power of information visualization to provide a chronological overview of the medication history, to enable zooming, sorting, and filtering the list, and to enable clicking a medication bar graph to reveal further details on demand.[32]

Backlog features

In addition to the features included in our online final product, we identified a set of backlog features and concepts that could not readily be incorporated into the interactive prototype. We have clarified most of the interaction design of these backlog features. The following section presents the backlog features and their respective visual mockups.

Clicking or tapping expands the row/bar, displaying additional details including dosing details, and dates and reasons for medication changes (Figure 4).

(Insert Figure 4)

Selecting a diagnosis in the problem list highlights corresponding medications in the timeline. In Figure 5, the diagnosis of “hypertension” was selected in the problem list, and three medications for hypertension are highlighted in an accent color, teal. This is called “brushing and linking” in the data visualization discipline.[33] Associating the readily available “therapeutic category” for a medication will not be as effective as using the clinician-assigned diagnosis. “The physician and patient need to know why this medication has been prescribed for this particular patient. Knowing that a drug is a beta-blocker (the therapeutic class) is not sufficient, because a beta-blocker might be used for any of these diagnoses: hypertension, angina, coronary artery disease, atrial fibrillation, supraventricular arrhythmias, tremor, migraine, and portal hypertension. The therapeutic class will often be meaningless to the patient.”[31]

(Insert Figure 5)

We included a static mini-timeline in our interactive table view of the medication list, available at http://inspiredehrs.org/medication-list/, and shown here in Figure 6. This interactive table view allows sorting by key columns, and filtering using the search field.

(Insert Figure 6)

Additional sketches in the Appendix show less refined concepts for additional display details or use cases.

Zooming shows increasing granularity, which could display medication adherence gaps, refill events, and under-dosing if corresponding patient adherence data and pharmacy dispensing data were reliably available, sketched in Appendix Figures 1 and 2. One example of quantitative measures of medication adherence is medication possession ratio (MPR)[34].

Projecting the timeline into the near future allows display of planned complex care transitions where several medication changes occur in a relatively short time interval. One example of such a complex care transition is the peri-procedural period where medications may be paused, used in reduced doses for a limited time, tapering (up or down) schedules are employed, or new temporary medications added (Appendix Figure 3).

We chose to display medication dosage as color intensity in a uniform height horizontal bar graph, but alternative displays are possible. An alternative timeline using height of the horizontal bar to convey dose strength is shown in Appendix Figure 4. It also displays examples of adherence gaps, partial adherence, taking more than the prescribed amount, and predicted duration of the prescription.

EVALUATION OF PROTOTYPE

Methods

Using group email solicitation, we recruited twenty-three physicians who practice in the ambulatory clinics of University of Missouri Health Care. We sampled for heterogeneity in gender, years since residency graduation, and years using electronic health records. Family medicine attending physicians formed the sample majority; smaller numbers of internal medicine attending physicians also participated.

The survey used multiple choice questions, asking participants to select the best possible answer (or answers). Qualtrics recorded the initiation time, time to first click, the time to last click, time to submit, and responses for each survey question. Task time was measured using the “time to submit”; the time between when a task was initiated and when the participant submitted a response. Task correctness was determined based on the comparison of the pre-determined response and the participant response.

To derive the questions for the survey, we began by identifying common ambulatory clinical scenarios in the management of hypertension, and which included a need to reference the prior medication history in the electronic health record. We reasoned that clinical scenarios would rely too much on the participants' medical knowledge and experience, and thus might confound the analysis of results. Therefore, we derived discrete, fundamental tasks from these common patient scenarios. See Table 3.

All data were identical across each visualization—the only difference was in the presentation of the data (table vs timeline formats). All medications had the same start date, end date, and dosage history. All medications were sorted by descending, alpha-numeric order. Participants were randomly assigned to either the table or timeline formats (resulting in uneven Ns for each item). See Supplemental Figures 6 and 7.

Results

The survey was activated a total of 35 times. Of those activations, 24 participants completed the demographics survey questions (Table 3). Of those participants, one participant dropped out and for that participant no responses were collected across any item.

Table 3. Demographic characteristics

Characteristic (*N* = 23)	*N* (%)
Gender	
Male	12 (52%)
Female	11 (48%)
Age group	
24–34 years old	6 (26%)

35–44 years old	4 (17%)
45–54 years old	5 (22%)
55–64 years old	7 (30%)
65–74 years old	1 (4%)
Computer skill	
Beginner	1 (4%)
Intermediate	18 (78%)
Expert	4 (17%)
Years of experience as a healthcare provider	
0–5 years	6 (26%)
6–10 years	3 (13%)
11–20 years	3 (13%)
21 years or more	11 (48%)

Of the remaining 23 participants, two participants dropped out at Item 5 and no responses were collected. One response to Item 1 was intentionally removed because the response time was 71035 seconds (19.76 hours), 256 times greater than the next longest response time. The participant's remaining item responses did not produce a noticeable outlier; and including or excluding these responses did not change the outcome significance of the study. Therefore, the remaining responses from this participant were included in the final model. Determining a successful response required the participant to answer the whole question correctly and partial credit was not applied (Table 4).

Table 4. Task Accuracy and Task Time of Table Compared to Timeline

Task	Table		Timeline		Mean difference	Table	Timeline	Mean time difference
	N	Answered correctly	*N*	Answered correctly		*Mean Time in seconds (SD)*	*Mean Time in seconds (SD)*	
1. Identifying current prescription on a medication history “*Based on the visualization provided, please identify which of the following is not a currently prescribed medication.”*	8	50%	14	64%	+14%	44 (22)	69 (37)	+25
2. Identifying past prescription on a medication history “*Based on the visualization provided, please check all past prescriptions. Our definition of ‘past prescriptions’ includes only medication prescribed AND not currently in use.”*	12	17%	11	91%	+74%	68 (22)	50 (17)	-18
3. Identify the length of time a medication has been prescribed “*Based on the visualization provided, how many years has Alendronate been prescribed to the patient?”*	9	44%	14	93%	+49%	22 (8)	16 (6)	-6
4. Identify new prescriptions in a given time	10	50%	13	62%	+12%	65 (24)	30 (12)	-35

interval *"Based on the visualization, select all new medications from the list below prescribed between 2012 and 2013. New medications are all medications with no record of any previous prescription to the patient."*								
5. Identify a dosage change in a given time interval *"Based on the visualization, identify all medications with a dosage change between 2013 and 2014."*	10	0%	11	18%	+18%	36 (18)	30 (8)	-6

Mean time difference is calculated as Timeline minus Table value.

Discussion

We expected that the data visualization timeline view would have been more accurate than the traditional medication history view. We found that physician accuracy increased across all five tasks, with especially large increases in performance in tasks 2 and 3. The low performance in task 5 suggests that some common medication-related EHR tasks may be so difficult that specific design considerations must be made for them to improve performance.

The timeline performed faster in 4 out of 5 tasks but did not reach statistical significance. Since these observations were performed in remote unsupervised testing, they may not be reflective of real world usage.

Data visualization tools such as the medication timeline can take advantage of the power and speed of the human brain's visual processing system. Features like preattentive attributes including color, size, shape, and proximity allow users to quickly spot treatment changes such as medication dose changes, and to perceive gaps such as medication adherence gaps. Data visualization also allows interactivity and cross category comparisons. These kinds of more complex tasks can be expected to be much faster with data visualization methods than with existing electronic health record user experiences. With the interactivity of data visualizations, a user can drill-in to explore any area of interest such as an individual medication event or a transition in medication doses. Being able to visually explore cross-category relationships such as those between a medication change and other data such as lab results or vital signs (blood pressure and weight) changes allows users to postulate causative correlations between these categories. Visually correlating a change in lab results after a medication change should be much easier than with current electronic health records display methods.

GENERAL DISCUSSION

Our goal was to produce a prototype example allowing physicians to understand a patient's complex medication list history in a single graphical view, thus reducing time, effort, and cognitive load while improving task speed and accuracy, thus enhancing safety. The timeline was intended for rapid learning and shared use by patient and physician, so visual simplicity was paramount. We limited the scope to the ambulatory primary care setting of patients with multi-morbidity chronic conditions.

The primary audience for our demonstration prototype is the community of health IT developer teams, offering clinically-inspired design examples, with participation from stakeholders from that community. Their participation helped root our design recommendations in the reality of the commercial development environment and marketplace. From personal communications, we are aware of a handful of vendors who have since pursued or are pursuing medication timeline functionality.

The interactive prototype is released for use free of charge, and the code for the prototypes is made available at https://github.com/goinvo/EHR/tree/master/timeline under the Apache 2.0 open source license. Our accompanying online guide “Inspired EHRs: Designing for Clinicians” explains the human factors science and information design principles incorporated into this model.

There are limitations to this design project. Evaluation of this timeline was completed using expert reviews from a group of clinicians (physicians, nurses, pharmacists), human factors researchers, usability practitioners, and volunteers from the EHR vendor community. Our pilot study was performed unsupervised, remotely, and had a small number of participants with weak statistical power. Further research is needed to show whether this prototype performs better than existing medication historical information displays. We learned from implementation efforts at one electronic health record vendor and one client organization that there is inconsistent and limited prescription dispense and adherence data being exchanged or available currently. The transmission of e-prescription details is inconsistent across commercial EHR and pharmacy software products thus limiting the consistent display of prescription instruction detail. Prescribers may write imprecise or non-standard dosing instructions, depending on the flexibility of the prescribing software. When the data is exchanged from EHR to e-prescribing hub to pharmacy software, or makes the return trip for a renewal request, the data may undergo transformation that introduces new ambiguity. What started the journey as discrete data elements, "lisinopril 10 mg; oral tablet; 1 tablet; 1 time a day", may get transformed to unstructured text "lisinopril 10 mg; 'TAKE ONE TABLET DAILY BY MOUTH'". Parsing the mixture of data formats to create a precise timeline display can be technically daunting.

Future efforts should include commercial production of medication timelines with our proposed features included or excluded based on the workflow it's intended for. Changing the zoom level could change the level of detail displayed making it easier to show more details as focus narrows; removing some details or features, adding others, and thus maintaining a clean and balanced design. Additional features could include cross-category comparisons if displayed inline or adjacent to time-based displays of other clinical information such as lab results, blood pressure, and weight, thus allowing quick, mental connections to relevant data with much less cognitive effort. Our prototype makes use of different shades of gray to convey dose strengths, but other techniques are worth considering and researching to validate speed, accuracy, and clarity of prescription and adherence data. Different considerations must be made when designing for the various tasks a provider performs at any given time.

Whether this tool can thrive in the commercial HIT marketplace remains to be seen. The SMART (Substitutable Medical Apps and Reusable Technology) project (https://smarthealthit.org) harnesses the FHIR (Fast Healthcare Interoperability Resources) from HL7 to create open solutions and tools for innovators to build applications that can connect to systems using the FHIR platform. Using this platform or FHIR standards, non-commercial or commercial developers could create a medication timeline app that could be deployed across any compatible EHR.

CONCLUSION

We have presented a design aimed at improving physician understanding of a patient's complex medication history, using a visualized medication timeline. The design was produced via iterative, rapid prototyping, with consistent feedback from several stakeholder groups. We believe that such a design would reduce the temporal and cognitive load placed on physicians when evaluating a patient's medication history, leading to improved and safer care.

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COMPETING INTERESTS:

None declared.

ETHICS APPROVAL:

University of Missouri Health Sciences Institutional Review Board

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