An Electronic Health Record Interface for Clinician Use in Inpatient Settings During Rounds

Acknowledgements

I would like to thank my thesis advisor, Professor Barbara Grosz, for being so receptive of my wish to get involved with her research and for her continued mentorship, guidance, and encouragement. I thank Shiri Assis-Hassid for her feedback and support and for regularly dispelling my confusion about my own work. I would like to thank Dr. Jody Lin, Dr. Lee Sanders, Dr. Hermioni Lokko, Dr. Katherine Rose, Dr. Yoshio Kaneko, and Sheila Enamandram for providing feedback on my designs. I would like to thank my mother for her daily words of encouragement. I would also like to thank my friends for their moral support.

Table of Contents

Chapter 1

Introduction

1.1 Project Motivation & Definition of an EHR

In every sector, technology is changing the way people interact with each other. In medicine, electronic health records (EHRs) digitize paper patient records to prevent information loss, increase access to information, and improve clinicians' understanding and retention of patient information. EHRs combine many elements of a patient's medical record, such as medication and allergy lists, past test results, and consultant notes with the ability to prescribe medication, complete orders, and input new notes, ultimately, with the goal of enhancing a clinician's ability to treat patients [1]. However, EHRs can only enhance a clinician's ability to treat patients if their design is intuitive and reflective of specific clinician needs, which is not always the case.

The recent adoption of EHRs in the United States was motivated by forces external to clinicians. The Health Information Technology for Economic and Clinical Health (HITECH) Act, within the American Recovery and Reinvestment Act of 2009, took effect when only 10% of United States hospitals had basic EHRs. The goal of the HITECH act was to increase the adoption of EHRs by subjecting hospitals that had not adopted EHRs by 2015 to fines. As a result, by 2015, 84% of U.S. Non-Federal Acute Care Hospitals had basic EHRs [17]. However, adoption does not automatically translate into enhancement. Current EHRs adopted during this transition are difficult to navigate and do not account for clinicians' needs. This incompatibility between the system's requirements and clinicians' needs overburdens clinicians in the patient room and encourages behavior that is antithetical to the EHR goals [18].

EHR interface designs that fail to support clinicians' needs force them to find workarounds, such as handwriting notes on paper, and increase their chance of experiencing clinician burnout, all of which lead to patient safety issues [6, 9]. This potential for patient harm makes it vital to design an EHR interface that supports clinicians' workflow. This thesis focuses on supporting clinicians through the use of EHRs in inpatient settings during rounds.

I decided to focus on EHR use during rounds, because many problems that clinicians encounter with EHR interface designs are exacerbated when clinicians are interacting with patients under time pressure. Rounds are a critical and short period for the care team and the patient to share results, patient status, and upcoming events. The goal of the thesis is to design an EHR interface for rounds that improves clinicians' rounding experience.

1.2 Literature Review

In an effort to address the interface design issues in current EHRs, researchers in informatics and design have worked with medical professionals to identify specific problems resulting from the use of EHRs in hospitals [3-9]. These studies informed me of the problems with current EHRs.

Through surveys, interviews, and contextual inquiry, the studies pinpoint reasons why clinicians, medical students, nurses, and attending clinicians have trouble using EHRs. These reasons vary from physicality and location of the system, to unintuitive interface designs and lack of support. In terms of physicality of the system, most literature studies EHRs that are located on desktop computers [3-6] though a few use iPads [7]. As a result of desktop computers' immobility, clinicians are required to allocate additional time at the end of their shifts to enter information into the EHRs [3,4]. Clinicians' frustration in response to the isolated location of the EHRs is only

exacerbated by interface designs that force them to click through many pages to access relevant information [5]. Additional interface design problems include inflexible note taking and data input, resulting in clinicians resorting to handwriting notes on paper, increasing the likelihood of error if, and when, they are transferred to the EHR [6].

The problems that arise through the use of EHRs differ depending on the context in which they are used. The inpatient setting is complex by nature, with patients often staying several days or weeks, resulting in the accumulation of many clinical notes and test results. Within the inpatient setting, I focused on EHR interface design problems that occur during rounds. Understanding the workflow of a clinician during rounds–including the timeline, goals, and tasks–helped identify which usability problems were relevant to this thesis. EHRs are used by clinicians in the patient room mostly to share information with care team members and with the patient rather than to input new information [8,9]. As a result, the design solutions in this thesis focus heavily on information extraction.

Existing literature maps out the workflow of clinicians, with and without EHRs, during their rounds. Lin [8] studied the distribution of work between team members during rounds which allowed him to propose EHR interface design suggestions for specific moments in the workflow. Collins [9] focused on the use of EHRs before, during, and after rounds. By charting the clinician's actions during rounds, without EHRs, I was able to understand the clinician's responsibilities and work habits.

1.3 Problem Statement & Project Scope

Current EHR designs do not sufficiently support clinicians in the patient's room. Specifically, EHRs disrupt the clinicians' workflow and require them to allocate additional time

to input information into the system after rounds. Existing literature [8,9] reveals that when EHRs are used in patient rooms, they are used to share information and take quick notes rather than to enter or organize information, but current designs do not facilitate these tasks. The objective of this thesis is to present an EHR interface design that maximizes clinicians' engagement with the patient by minimizing the time needed to extract information from the interface, accommodates clinicians' existing practices, and dynamically integrates information. This thesis identifies several design choices that successfully reflect the design objectives by presenting a relevant subset of information, dynamically integrating data, and prioritizing visualizations when appropriate. This thesis builds on the work done by Assis-Hassid et al [24].

Chapter 2

Methods & Tools

2.1 Design Objectives

Current EHRs do not sufficiently support clinicians during rounds, because the systems are created to store structured patient information and do not account for clinicians' rounding practices. I present three design objectives for this thesis which aim to change the clinician rounding experience through a novel EHR interface design. The objectives are to design an EHR interface for rounding that:

1. Maximizes the clinicians' engagement with the patient by minimizing the time spent interpreting results.
2. Accommodates clinicians' natural behaviors and desired actions.
3. Helps clinicians interpret and extract information by integrating traditionally separate components.

2.2 User-centered Design Process

Within the EHR interface design, the design objectives are realized through design choices. The design choices emerged from the design objectives through an iterative process of user-centered design. User-centered design (UCD) believes that users of a system, not the designers, are the most knowledgeable about the needs of the users. The UCD process allows designers to uncover the user's needs and translate these into a design. The UCD process can be separated into

three phases: inspiration, ideation, and implementation [20]. This thesis focuses on the first two phases.

The design objectives were formed during the inspiration phase from existing literature on the usability problems in EHRs and a qualitative study conducted by Assis-Hassid [24]. Design choices were made, evaluated, and refined during the ideation phase. For this thesis, the ideation phase included an iterative process of prototype development and user feedback. Prototypes were used as a tool to simulate a scenario for users. Through this scenario, I was able to identify strengths and weaknesses of the design [20]. The form of each prototype differed depending on the stage in the process, but feedback on each prototype helped answer the following questions:

1. What patient information is relevant to the clinicians as they are rounding?
2. How should this information be visualized and integrated?
3. How do clinicians see this design fitting into their existing rounding routines and practices?

The answers to these questions helped justify design choices that bring the EHR interface closer to achieving the design objectives. Chapter 3 outlines the first two prototypes and the feedback for each prototype and Chapter 4 discusses the final design prototype and feedback on the final design.

2.3 Tools

I used PowerPoint to design Prototype 1 and Adobe XD (Experience Design) for Prototype 2 and the final design. I used Adobe XD to create interactions between buttons and screens. For each prototype, I used patient medical information from the MIMIC-III dataset of anonymized clinical records [21]. I developed an interview guide (Appendix A) for the first interview to understand the clinician workflow and get feedback on the prototype. The interviews for Prototype

2 and the final design focused only on design feedback. For Prototype 2 and the final design, the users performed different tasks (Appendix B) to help elicit feedback.

Chapter 3

Design Process

3.1 Prototype 1: Key Components of the Interface

Prototype 1 (Figures 1-3) presents multiple visualizations of various components. Components are individual pieces of patient information like medication list, clinical notes, and lab results, whose visualization affects a clinician's ability to understand a patient's health status. The components represented in Prototype 1 are repeated across Figures 1-3 with different visualizations, but each Figure does not represent a complete EHR interface screen. As a result, the prototype focuses on the functions and information that should be included in the design to accommodate the behaviors and actions of clinicians (Objective 2) and to understand how to organize components (Objective 3) before moving to a complete EHR interface screen in Prototype 2. All prototypes assumed that the clinician would be using a tablet to access the system.

3.1.1 Prototype 1: Design Walkthrough

Figure 1 is designed to highlight the difference between textual and visual representations of information and to consider the possibility of automating information organization. Figure 1 is divided into two halves. The top half shows text integrated with visuals, with an automatic selection of potentially important information. The visuals are intended to help the clinician synthesize information, so that he or she can spend less time on the screen (Objective 1). The bottom half includes only textual patient information to get feedback on the type of information that is relevant to display in this context (Objective 2).

The top half of Figure 1 shows a short summary of the patient demographic information, reason for hospital admission, and patient medical history. Below the patient summary, a blue header displays five buttons. These buttons represent a subset of patient documents and an automatically aggregated set of recommendations. Four of the buttons are grey to denote that the documents are displayed below the header. The documents are chosen based on perceived relevance, but the clinician can change which documents are automatically displayed. The automation aims to minimize the actions required of the clinician to maximize his or her ability to engage with the patient (Objective 1). Within the document display, the CT Scan is paired with the impression note about the CT Scan and the information in the Cranial Nerve Exam is separated based on body part and linked directly to that body part in the diagram. Both of these choices group related information to help the clinician synthesize results (Objective 3). Between the blue header and the Cranial Nerve Exam, there are three boxes that correspond to the *Recommendations* button. *Recommendations* automatically aggregates information from patient records to suggest a care plan for the patient.

The bottom half of Figure 1 contains multiple patient documents. There are three sections of notes: *History of Present Illness*, *Most Recent Physical Exam* (objective patient measures), and *Pertinent Results* (consultant notes and images). None of the files displayed are condensed or summarized and the clinician must click the graph icon or image icon to see graphs and images in a separate page. An integrated EHR interface design would not contain this much text, but this visualization helps get feedback on the amount of text that should be displayed and the importance of numerical and textual information when displayed with graphs and images (Objective 3).

Patient Info & History

Patient Name DOB, Sex
Service: NEUROSURGERY
Allergies: no known allergies
Chief Complaint: left sided brain lesion

Major Surgical or Invasive Procedure: 2/25 – left craniotomy for mass resection
Family History: NC

Attending Name

Social History: Lives with his wife. Retired, works parttime driving a school bus.

Past Medical History: Cardiac arrhythmia, pacemaker in place, prostate cancer with prostatectomy, and hypertension

CRANIAL NERVE EXAM | 2/28 CT HEAD SCAN | 2/28 CT HEAD IMPRESSION | 2/25 CT HEAD SCAN | RECOMMEN-DATIONS

RECOMMENDATION
Increase metaprolol XL dose to 100mg Qday.

GOAL OF RECOMMENDATION
Decrease intermittent heart rate of 130-170s to stable range.

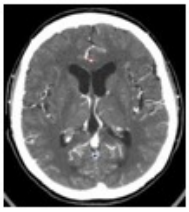
SIDE EFFECTS OF RECOMMENDATION
List of metaprolol side effects.

Cranial Nerve Exam

- Pupils are equal and reactive to light
- 4 mm to 2 mm bilaterally
- Extraocular movements are full
- No nystagmus
- Visual fields full to confrontation
- Funduscopic exam reveals sharp disk margins bilaterally
- Face is symmetric
- Facial sensation, hearing intact bilaterally

- Tongue midline
- Palate goes up in the midline
- Sternocleidomastoids and upper trapezius are strong

2/28 Head CT c/ contrast scan



2/28 Head CT c/ contrast: IMPRESSION:
Status post left frontal craniotomy changes with improvement of pneumocephalus and stable 3 mm left to right midline shift; focus of hemorrhage with/without residual tumor in the resection bed is similar in appearance to prior exam but now with more surrounding vasogenic edema. Stable appearance of subarachnoid hemmorage. Followup to assess for residual tumor / interval change.

History of Present Illness:
62 y/o left-handed man here for follow up of his left sphenoid meningioma. Seen last 11/17/2149 and his head CT showed growth of the left sphenoid meningioma.
He is seizure free.
Today, he is here with his wife and daughter. Does not have headache, nausea, vomiting, urinary incontinence, or fall.
His neurological problem began on 6/22/2142 when he became confused and disoriented in a hotel bathroom. At that time, he was visiting his daughter for a wedding. His wife found him slumped over in the bath tub. According to her, his eyes looked funny. He could not stand up. His verbal output did not make sense. He was brought to Dr. C Hospital in Placentia, CA. He woke up 7 to 8 hours later in the ER. He felt very tired after the event. He was hospitalized from 6/22/2142 to 6/25/2142.
He had a cardiac pacemaker placement due to irregular heart rate and bradycardia. He also had a head MRI that showed a less than 1 cm diameter sphenoid meningioma.

Most Recent Physical Exam

Temperature:	Blood Pressure:	Pulse:	Respiration:
97.8 F	150/92	80	16
- 0.8 F	- 4 / - 2	+ 5	+ 1

Skin has full turgor.
HEENT is unremarkable.
Neck is supple.
Cardiac exam reveals regular rate and rhythms.
Lungs are clear. **Abdomen** is soft with good bowel sounds.
Neurological Exam: His Karnofsky Performance Score is 100. He is awake, alert, and oriented times 3. His language is fluent with good comprehension. His recent recall is intact.

Cranial Nerve Exam: pupils are equal and reactive to light, 4 mm to 2 mm bilaterally. Extraocular movements are full. No nystagmus. Visual fields full to confrontation. Funduscopic exam, reveals sharp disk margins bilaterally. Face is symmetric. Facial sensation, hearing intact bilaterally. Tongue midline. Palate goes up in the midline. Sternocleidomastoids and upper trapezius are strong.

Motor Exam: He does not have a drift. His muscle strengths are 5-16 at all muscle groups. His muscle tone is normal. His reflexes are 0 in upper and lower extremities bilaterally. His ankle jerks are absent. His toes are down going. Sensory examination is intact to touch and proprioception. Coordination examination does not reveal dysmetria. His gait is normal. He can do tandem. He does not have a Romberg.

Pertinent Results

2/25: CT Head: IMPRESSION:
1. Likely meningioma along the greater [Doctor First Name 362] of the left sphenoid bone, measuring 18 mm in diameter, unchanged since the most recent study of 11/2149, with reactive bony changes, as above.
2. Bifrontal cortical atrophy, which has progressed slightly over the series of the studies since the earliest studies of 2142.

2/25: CT Head: IMPRESSION:
Expected post-operative changes with the left frontal craniotomy including subcutaneous air and soft tissue swelling, moderate pneumocephalus overlying predominantly the bilateral frontal lobes, and foci of hemorrhage in the surgical bed. No evidencce of residual tumor on this non contrast CT.

2/26 CXR: FINDINGS:
The lung volumes are rather low. There is moderate cardiomegaly without evidence of overt pulmonary edema. No areas of atelectasis or pneumonia. Right pectoral pacemaker in situ, with correct lead placement.

2/28 Head CT c/ contrast: IMPRESSION:
Status post left frontal craniotomy changes with improvement of pneumocephalus and stable 3 mm left to right midline shift; focus of hemorrhage with/without residual tumor in the resection bed is similar in appearance to prior exam but now with more surrounding vasogenic edema. Stable appearance of subarachnoid hemmorage. Followup to assess for residual tumor / interval change.

Figure 1

The top half of Figure 2 shows *Patient Information and History*, *Medication Timeline*, *Patient Vitals*, and *Patient Lab Results*. The *Patient Information and History* is organized in a square box; this distinguishes itself less from the other components than the rectangular box used in Screen 1 did. Below *Patient Information and History*, the patient's current medications are displayed graphically in *Medication Timeline*. Each medication is graphed starting from the prescription date and includes dosage information and side effects. The clinician can also search drug interactions between medications. *Patient Vitals* displays the last four days of five vital measurements, four are displayed numerically and one, blood pressure, is displayed both numerically and graphically which helps the clinician interpret the changes in measurements. Below *Patient Vitals*, *Patient Lab Results* charts recent lab results. The results are separated based on result type and, for each document, there are categories for images, values, and comments, so the clinician does not even need to open the document to understand the results (Objective 1).

The bottom half of Figure 2 includes two different visualizations of *Patient Documents*, an *Imaging Result*, and an open *Clinical Note*. The *Patient Documents* visualization in the top left corner lists the documents and includes an icon to show if a document is currently open (concentric circles) or has been opened (check box). The second *Patient Documents* visualization in the bottom left corner displays the documents graphically and separates them into different categories (e.g., notes, results, new diagnoses). The separation of documents into categories helps track the patient's hospital journey. *Clinical Note by Dr. Y* formats the note by topic and synthesizes the information to make all the information visible in the allocated space.

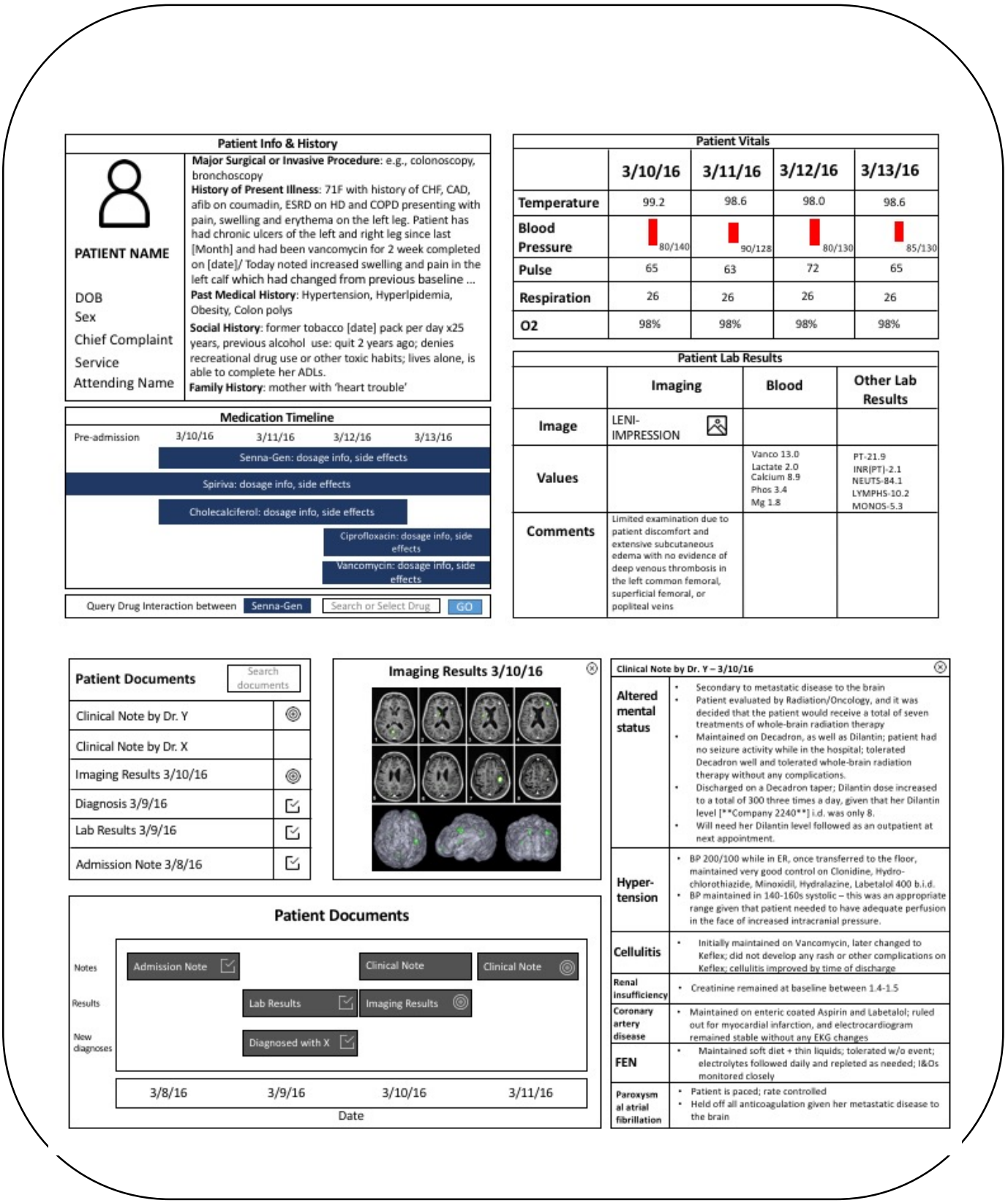

Patient Info & History
PATIENT NAME
DOB
Sex
Chief Complaint
Service
Attending Name
Major Surgical or Invasive Procedure: e.g., colonoscopy, bronchoscopy
History of Present Illness: 71F with history of CHF, CAD, afib on coumadin, ESRD on HD and COPD presenting with pain, swelling and erythema on the left leg. Patient has had chronic ulcers of the left and right leg since last [Month] and had been vancomycin for 2 week completed on [date]/ Today noted increased swelling and pain in the left calf which had changed from previous baseline ...
Past Medical History: Hypertension, Hyperlpidemia, Obesity, Colon polys
Social History: former tobacco [date] pack per day x25 years, previous alcohol use: quit 2 years ago; denies recreational drug use or other toxic habits; lives alone, is able to complete her ADLs.
Family History: mother with 'heart trouble'
Patient Vitals
3/10/16
3/11/16
3/12/16
3/13/16
Temperature
99.2
98.6
98.0
98.6
Blood Pressure
80/140
90/128
80/130
85/130
Pulse
65
63
72
65
Respiration
26
26
26
26
O2
98%
98%
98%
98%
Patient Lab Results
Imaging
Blood
Other Lab Results
Image
LENI-IMPRESSION
Values
Vanco 13.0
Lactate 2.0
Calcium 8.9
Phos 3.4
Mg 1.8
PT-21.9
INR(PT)-2.1
NEUTS-84.1
LYMPHS-10.2
MONOS-5.3
Comments
Limited examination due to patient discomfort and extensive subcutaneous edema with no evidence of deep venous thrombosis in the left common femoral, superficial femoral, or popliteal veins
Medication Timeline
Pre-admission
3/10/16
3/11/16
3/12/16
3/13/16
Senna-Gen: dosage info, side effects
Spiriva: dosage info, side effects
Cholecalciferol: dosage info, side effects
Ciprofloxacin: dosage info, side effects
Vancomycin: dosage info, side effects
Query Drug Interaction between
Senna-Gen
Search or Select Drug
GO
Patient Documents
Search documents
Clinical Note by Dr. Y
Clinical Note by Dr. X
Imaging Results 3/10/16
Diagnosis 3/9/16
Lab Results 3/9/16
Admission Note 3/8/16
Imaging Results 3/10/16
Clinical Note by Dr. Y – 3/10/16
Altered mental status
Secondary to metastatic disease to the brain
Patient evaluated by Radiation/Oncology, and it was decided that the patient would receive a total of seven treatments of whole-brain radiation therapy
Maintained on Decadron, as well as Dilantin; patient had no seizure activity while in the hospital; tolerated Decadron well and tolerated whole-brain radiation therapy without any complications.
Discharged on a Decadron taper; Dilantin dose increased to a total of 300 three times a day, given that her Dilantin level [**Company 2240**] i.d. was only 8.
Will need her Dilantin level followed as an outpatient at next appointment.
Hyper-tension
BP 200/100 while in ER, once transferred to the floor, maintained very good control on Clonidine, Hydro-chlorothiazide, Minoxidil, Hydralazine, Labetalol 400 b.i.d.
BP maintained in 140-160s systolic – this was an appropriate range given that patient needed to have adequate perfusion in the face of increased intracranial pressure.
Cellulitis
Initially maintained on Vancomycin, later changed to Keflex; did not develop any rash or other complications on Keflex; cellulitis improved by time of discharge
Renal insufficiency
Creatinine remained at baseline between 1.4-1.5
Coronary artery disease
Maintained on enteric coated Aspirin and Labetalol; ruled out for myocardial infarction, and electrocardiogram remained stable without any EKG changes
FEN
Maintained soft diet + thin liquids; tolerated w/o event; electrolytes followed daily and repleted as needed; I&Os monitored closely
Paroxysmal atrial fibrillation
Patient is paced; rate controlled
Held off all anticoagulation given her metastatic disease to the brain
Patient Documents
Notes
Results
New diagnoses
Admission Note
Clinical Note
Clinical Note
Lab Results
Imaging Results
Diagnosed with X
3/8/16
3/9/16
3/10/16
3/11/16
Date

Figure 2

Figure 3 has several of the same components as Figure 2. The new components are *Medical Paper Search*, *Patient Comparison*, *Blood Pressure by Day*, *Clinical Note by Dr. Y*, and *Hospital Course Timeline*.

Medical Paper Search displays the titles of two papers based on a medical query and includes a summary of each paper. This feature is based on work by Elhadad et al. [23] and would help the clinician quickly understand the queried information (Objective 3). *Patient Comparison* uses different patient features to determine similarity between patients to see how a change in medication might affect one patient based on how similar patients have reacted. Both *Medical Paper Search* and *Patient Comparison* offer desirable features to the clinician, but they might require too much time and thought (opposite of Objective 1) to be relevant during rounds.

Blood Pressure by Day presents a graph with relevant comments from patient notes embedded in the graph. The clinician can read comments related to a change in the patient's vital signs while looking at the graph.

Clinical Note by Dr. Y differs from *Clinical Note* in Screen 2, because it is not summarized. The non-summarized note is separated into sections which the clinician clicks to expand. This change was made to see how important complete sentences are to a clinician when reviewing notes.

Hospital Course Timeline charts patient events by date. The timeline represents the patient journey by combining subjective and objective measures compiled during the patient's stay. The patient event categories are complaints, procedure, medication change, lab results, and location. This timeline automatically combines different types of patient information for the clinician's benefit (Objective 3).

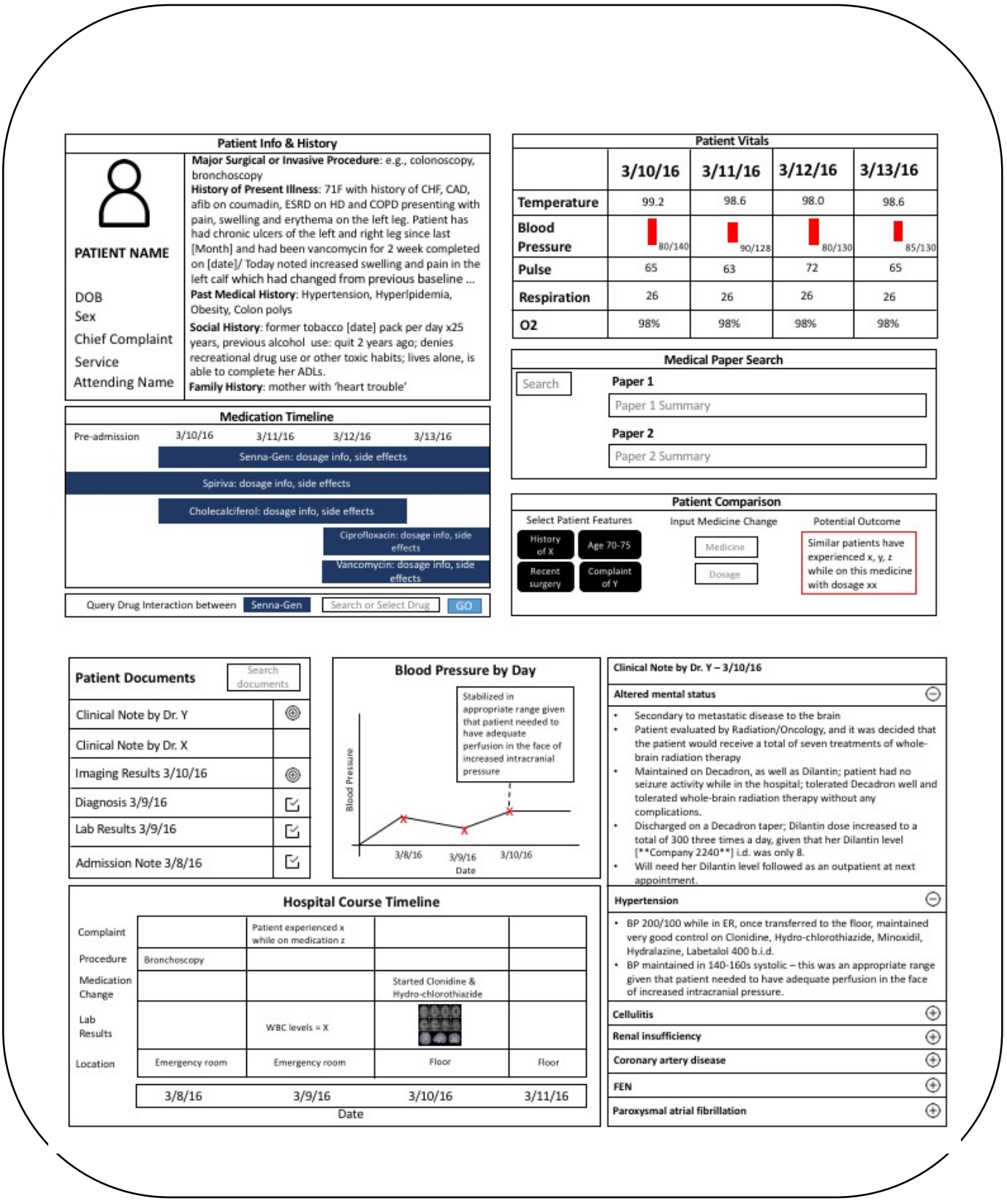

Patient Info & History
PATIENT NAME
DOB
Sex
Chief Complaint
Service
Attending Name
Major Surgical or Invasive Procedure: e.g., colonoscopy, bronchoscopy
History of Present Illness: 71F with history of CHF, CAD, afib on coumadin, ESRD on HD and COPD presenting with pain, swelling and erythema on the left leg. Patient has had chronic ulcers of the left and right leg since last [Month] and had been vancomycin for 2 week completed on [date]/ Today noted increased swelling and pain in the left calf which had changed from previous baseline ...
Past Medical History: Hypertension, Hyperlpidemia, Obesity, Colon polys
Social History: former tobacco [date] pack per day x25 years, previous alcohol use: quit 2 years ago; denies recreational drug use or other toxic habits; lives alone, is able to complete her ADLs.
Family History: mother with 'heart trouble'
Patient Vitals
3/10/16
3/11/16
3/12/16
3/13/16
Temperature
99.2
98.6
98.0
98.6
Blood Pressure
80/140
90/128
80/130
85/130
Pulse
65
63
72
65
Respiration
26
26
26
26
O2
98%
98%
98%
98%
Medical Paper Search
Search
Paper 1
Paper 1 Summary
Paper 2
Paper 2 Summary
Medication Timeline
Pre-admission
3/10/16
3/11/16
3/12/16
3/13/16
Senna-Gen: dosage info, side effects
Spiriva: dosage info, side effects
Cholecalciferol: dosage info, side effects
Ciprofloxacin: dosage info, side effects
Vancomycin: dosage info, side effects
Query Drug Interaction between
Senna-Gen
Search or Select Drug
GO
Patient Comparison
Select Patient Features
History of X
Age 70-75
Recent surgery
Complaint of Y
Input Medicine Change
Medicine
Dosage
Potential Outcome
Similar patients have experienced x, y, z while on this medicine with dosage xx
Patient Documents
Search documents
Clinical Note by Dr. Y
Clinical Note by Dr. X
Imaging Results 3/10/16
Diagnosis 3/9/16
Lab Results 3/9/16
Admission Note 3/8/16
Blood Pressure by Day
Stabilized in appropriate range given that patient needed to have adequate perfusion in the face of increased intracranial pressure
Blood Pressure
3/8/16
3/9/16
3/10/16
Date
Clinical Note by Dr. Y – 3/10/16
Altered mental status
Secondary to metastatic disease to the brain
Patient evaluated by Radiation/Oncology, and it was decided that the patient would receive a total of seven treatments of whole-brain radiation therapy
Maintained on Decadron, as well as Dilantin; patient had no seizure activity while in the hospital; tolerated Decadron well and tolerated whole-brain radiation therapy without any complications.
Discharged on a Decadron taper; Dilantin dose increased to a total of 300 three times a day, given that her Dilantin level [**Company 2240**] i.d. was only 8.
Will need her Dilantin level followed as an outpatient at next appointment.
Hypertension
BP 200/100 while in ER, once transferred to the floor, maintained very good control on Clonidine, Hydro-chlorothiazide, Minoxidil, Hydralazine, Labetalol 400 b.i.d.
BP maintained in 140-160s systolic – this was an appropriate range given that patient needed to have adequate perfusion in the face of increased intracranial pressure.
Cellulitis
Renal insufficiency
Coronary artery disease
FEN
Paroxysmal atrial fibrillation
Hospital Course Timeline
Complaint
Patient experienced x while on medication z
Procedure
Bronchoscopy
Medication Change
Started Clonidine & Hydro-chlorothiazide
Lab Results
WBC levels = X
Location
Emergency room
Emergency room
Floor
Floor
3/8/16
3/9/16
3/10/16
3/11/16
Date

Figure 3

3.1.2 Prototype 1: Feedback

I conducted an interview with Dr. A, a hospitalist, to get more information about the clinician's rounding workflow and to get feedback on Prototype 1. The details of the interview process are outlined in Appendix A. Feedback on Prototype 1 helped measure the effectiveness of certain high-level design choices (e.g., patient information and features to include in the EHR) for creating an interface design that accommodates clinicians' actions (Objective 2) and integrates patient information (Objective 3). The insights that emerged from the feedback are based on one interview with Dr. A, so they do not reflect all clinicians' or all departments' practices. I share three insights that emerged from the interview:

1. Clinicians check patient records before entering the patient room, so information displayed on EHRs during rounds should only show a relevant subset of information for clinicians to quickly scan.

   Dr. A reported taking time in the morning to go through each patient record before rounding, so Dr. A enters the patient room knowing the patient's condition and has notes indicating the goals of the visit. Dr. A does not need to or have the time to look through all the patient's information when Dr. A is in the patient room. As a result, not all patient data should be presented on the EHR screen during rounds, but the information that is presented should be interpretable at a glance and automatically selected based on relevance.

2. Graphical representations of patient data (e.g., lab results, vitals, document lists) help visualize the patient's hospital journey and help clinicians quickly interpret patient information.

   By combining temporal and numerical data with visual cues, clinicians are able to more quickly interpret the relationship between data points (Objective 3). This is potentially relevant

for EHR components like patient vitals, lab results, and medication lists. An intuitive representation of these components increases the speed with which clinicians can interpret information in the patient room. *Medication Timeline* and *Hospital Course Timeline* received positive feedback on their concepts, because the visualization of the document lists has a dual purpose of conveying information about a patient's stay and serving as a way to open the documents.

3. Unstructured, handwritten notes give clinicians the flexibility to record details and reminders as they appear, but they still require clinicians to structure the information as they enter it into the EHR after rounds.

   Dr. A handwrites comments prior to visiting the patient, continues writing on this list in the patient room and then refers to this list after completing rounds. Although this exact style of note taking is not generalizable to all clinicians, it does reveal an intuitive way of capturing information that should be supported in EHRs (Objective 2). In its current form, handwriting notes on separate pages increases the risk of losing information and requires clinicians to add notes into the system later. A digital mechanism that allows clinicians to quickly enter unstructured information would increase the amount of information recorded in the EHR and minimize repeated work (Objective 1).

The feedback on Prototype 1 indicates that integrating and visualizing patient information (Objective 3) helps clinicians understand the patient's journey. Clinicians enter the patient room knowing the patient's medical updates, so they only need to skim results from the screen rather than take the time to interpret the results (Objective 2). Clinicians would benefit from being able

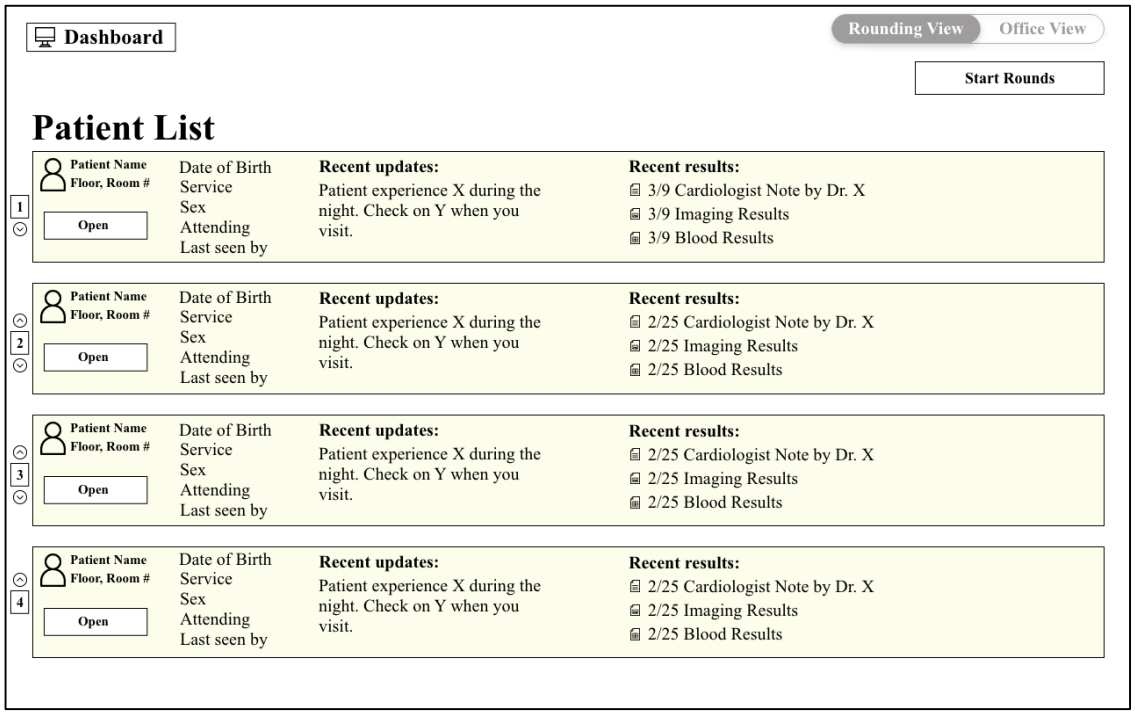
to take notes in an unstructured way on the EHR screen which could then be adapted to fit the structured needs of a clinical note (Objective 2).

3.2 Prototype 2: Interactive Prototype

Prototype 2 factors in feedback from Prototype 1 and presents integrated EHR screens for clinician use during rounds. The interactivity mimics the experience of using a functional EHR to understand how effective the integrated interface design is for quickly extracting and entering rounding information (Objective 1).

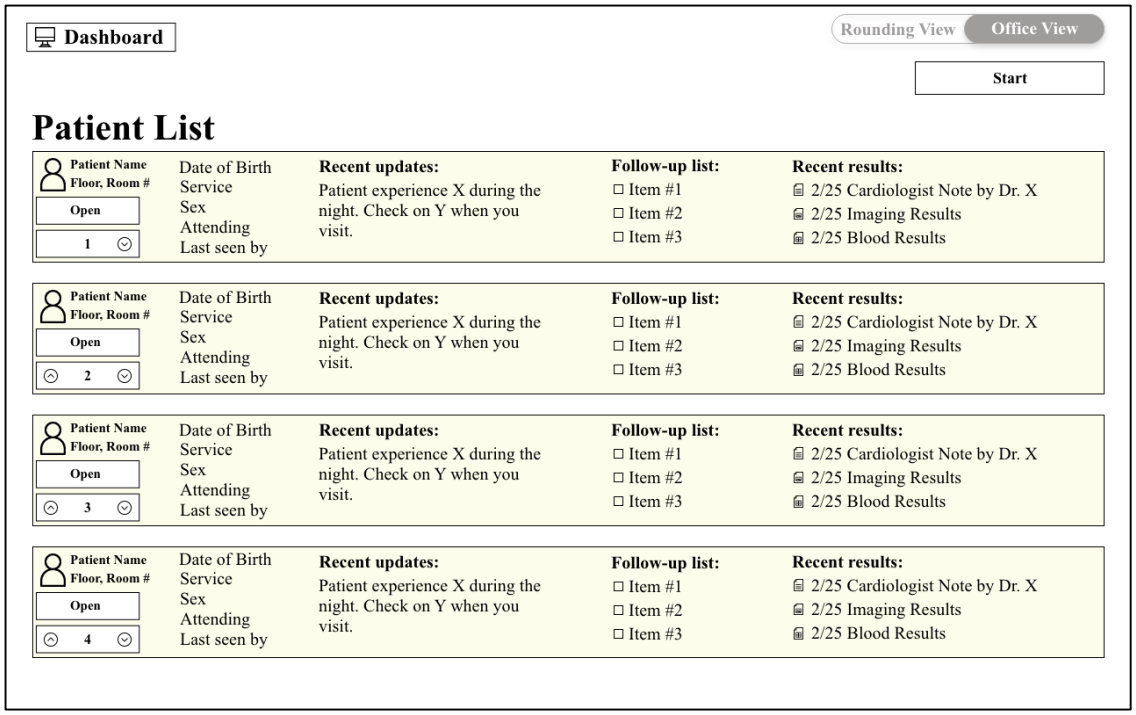
3.2.1 Prototype 2: Design Walkthrough

Screen 1 lists all the clinician's patients for rounds. There are two patient list settings, one for preparing for rounds (Office View) and another for performing rounds (Rounding View). Screen 1 shows the patient list in "Rounding View". Both settings list the same patients, but show different patient information to reflect the clinician's needs for rounding and pre-rounding. The clinician clicks "Order Patients by" to order patients by room number, acuity, language, last name, or primary service. Each patient section includes basic patient information, relevant recent updates drawn from overnight notes, and recent results. The clinician can open a patient record by clicking "Open" on the patient's section, clicking "Start Rounds", or clicking an icon associated with a recent result.



Screen 1: Patient List in Rounding View

Screen 2 displays the patient list in the “Office View” setting. The only difference between Screen 1 and Screen 2 is the additional “Follow-up list” in Screen 2. The “Follow-up list” shows which items are still pending from previous visits.

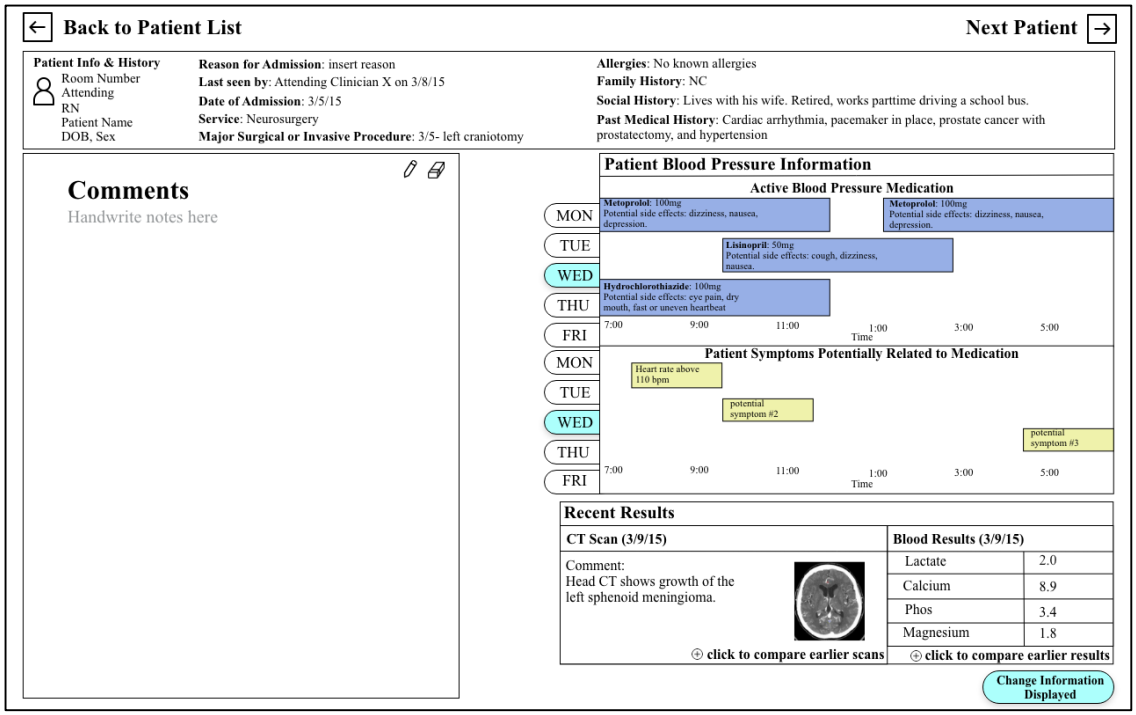


Screen 2: Patient List in Office View

The clinician arrives on Screen 3 by clicking “Start Rounds” or “Open” from an individual patient summary on Screen 1. The top of Screen 3 is *Patient Information and History*, which appeared originally in Figure 1 of Prototype 1. Screen 3 is otherwise divided into the left and right side. The left side leaves space to write reminders and the right side contains various patient data. Within *Reminders*, the clinician selects the pen icon to handwrite to-do items, general notes, and follow-ups on the page. The clinician can even use the pen to markup information outside of the designated *Reminders* section. The handwritten notes are automatically translated into text. The goal of the handwriting recognition technology is to allow the clinician to take notes as he or she naturally would and then translate the notes into text to improve legibility and keep notes in a format consistent with later documentation needs (Objective 2).

The right side of Screen 3 contains two distinct components: *Patient Blood Pressure Information* (*Active Blood Pressure Medication* & *Patient Symptoms Potentially Related to Medication*) and *Recent Results*. The clinician uses *Active Blood Pressure Medication* to see the length that an administered medication is active, as visualized by the blue rectangles that span the active time and contain the medication name, dosage information, and potential side effects. This adds temporal information to a previously static medication list to help the clinician understand more about the patient’s day (Objective 3). *Patient Symptoms Potentially Related to Medication* does as its title suggests and charts reported patient symptoms, pulled from various notes, across the day to provide additional insights into how a patient is responding to medication. The *Patient Symptoms* chart is placed below the medication timeline to signal a relationship between the two. *Recent Results* automatically populates with the latest results that have been added to the patient’s record, which are currently *CT Scan* and *Blood Results*. The automatic selection of results prominently presents recent information to minimize the time needed to find the results, since the

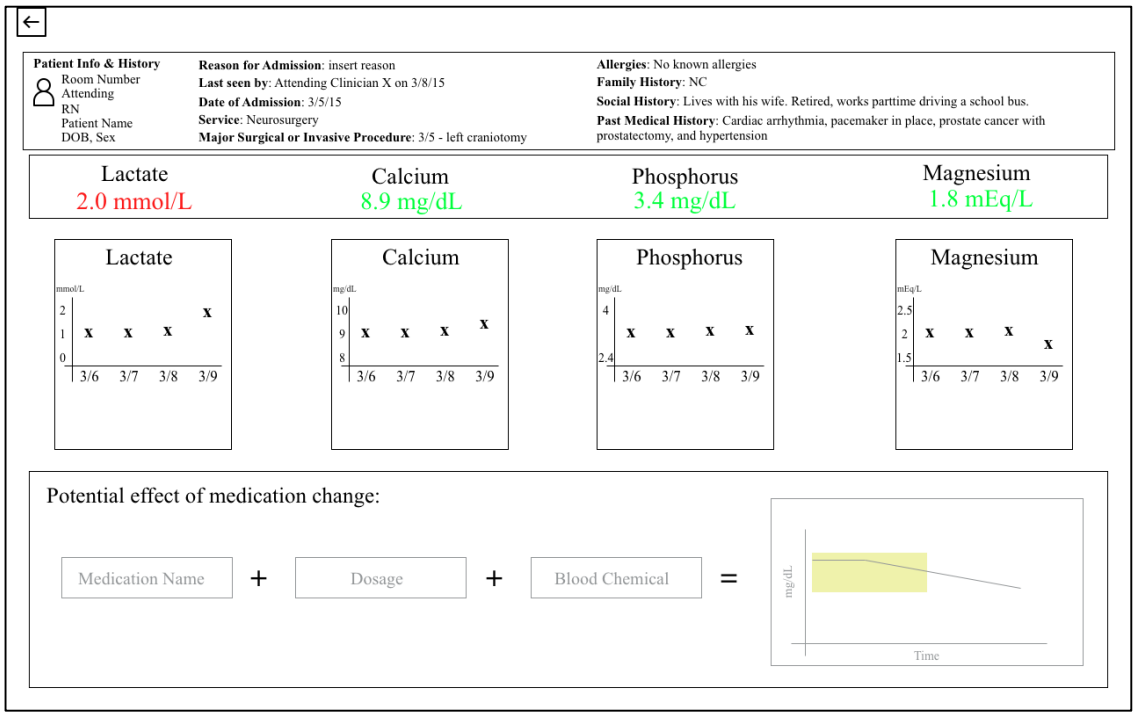
clinician will be most interested in sharing these results (Objective 1). The complete displays of *CT Scan* and *Blood Result*s are visible in Screen 4 and 5, respectively, and allow the clinician to compare values with earlier results, see larger images, and write comments.



Screen 3: Patient Rounding Page

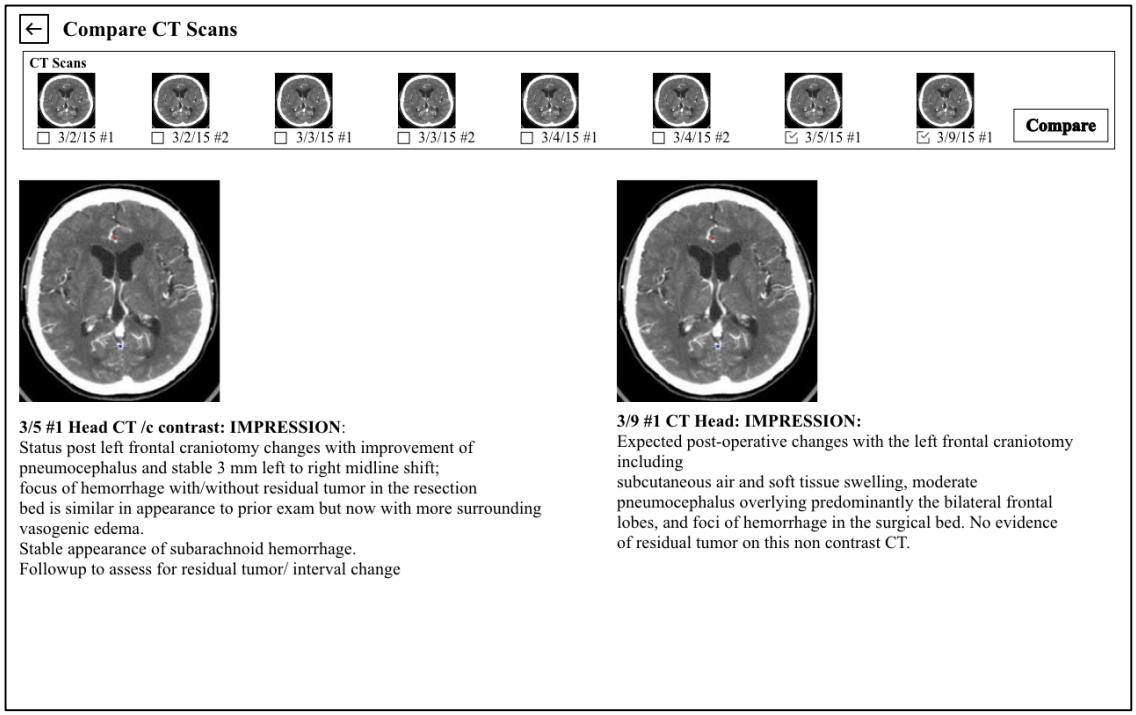
The “click to compare earlier results” button in *Blood Results* on Screen 3 leads to Screen 4. The blood results displayed on Screen 3 show only a preview of the most recent values, but the clinician might want to know how each value compares to earlier results or normal ranges. As a result, Screen 4 shows the current blood concentration number for each chemical in green if it is in range and red if it is out of range with a supplemental graph for each chemical.

The clinician manually inputs a potential medication, dosage, and blood chemical in *Potential effect of medication change* to see how a change in dosage or a new medication might affect patient vital measurements.



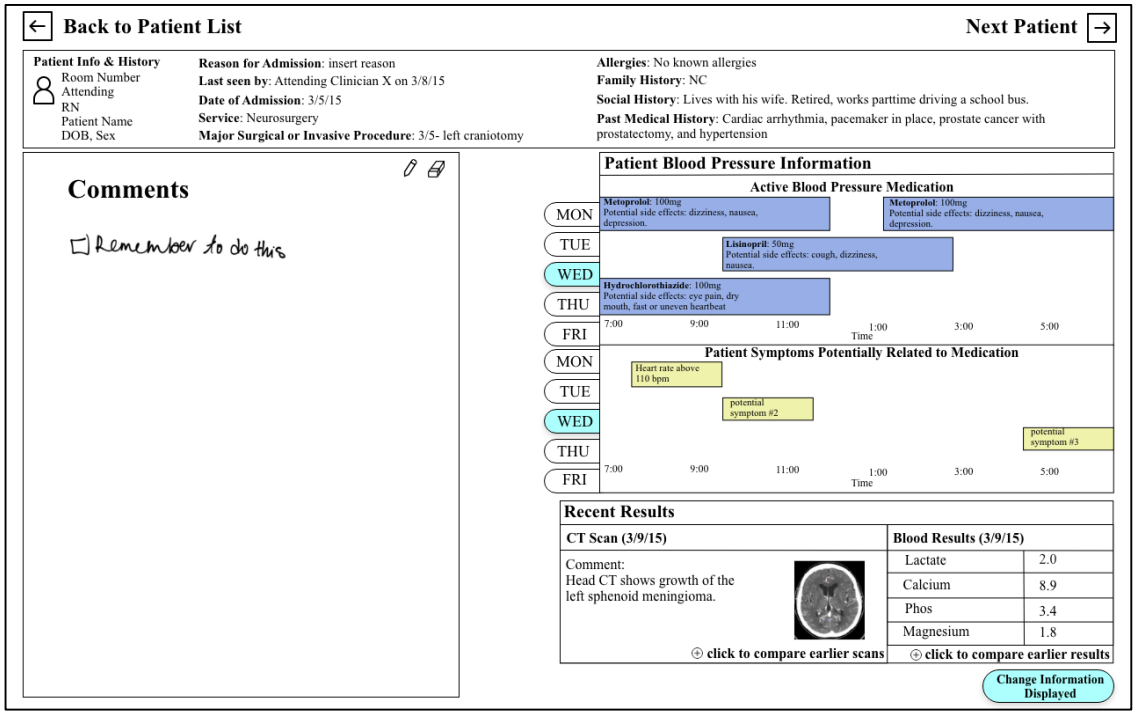
Screen 4: Blood Results

The “click to compare earlier scans” button in *CT Scan* on Screen 3 leads to Screen 5. On Screen 5, the clinician can select multiple scans to view at once and see earlier comments about the scan, if there are any.



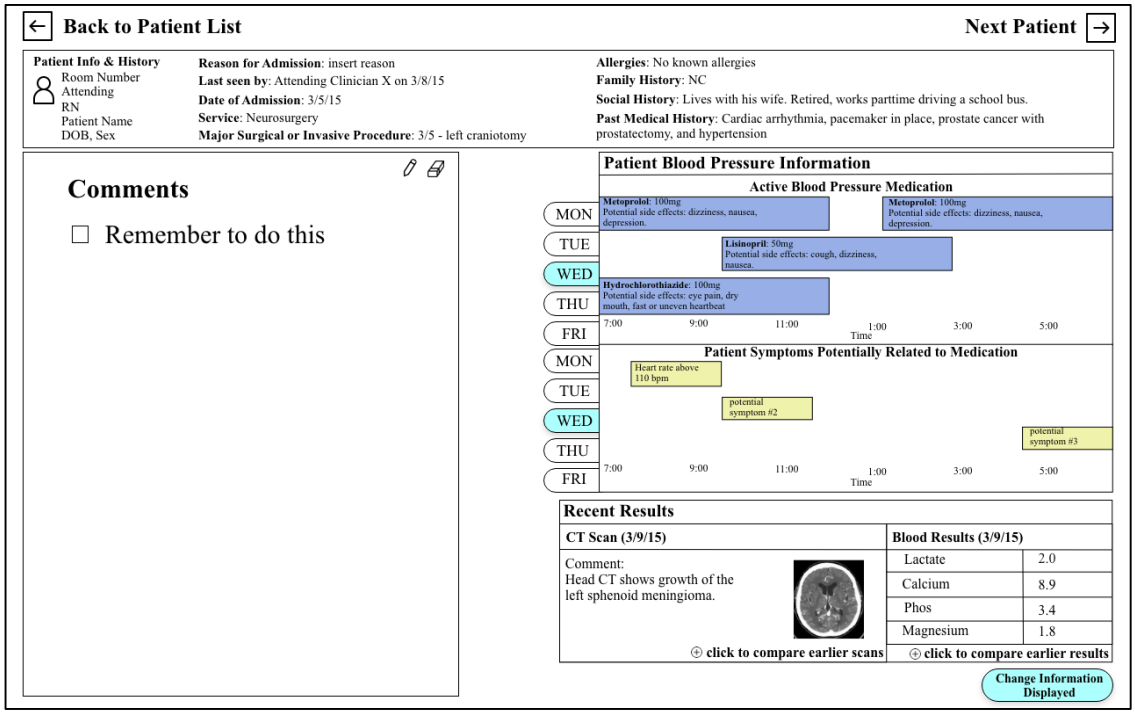
Screen 5: CT Scan

Clicking the pen icon in *Reminders* on Screen 3 allows the clinician to handwrite notes. Screen 6 shows an example of what a handwritten note would look like.



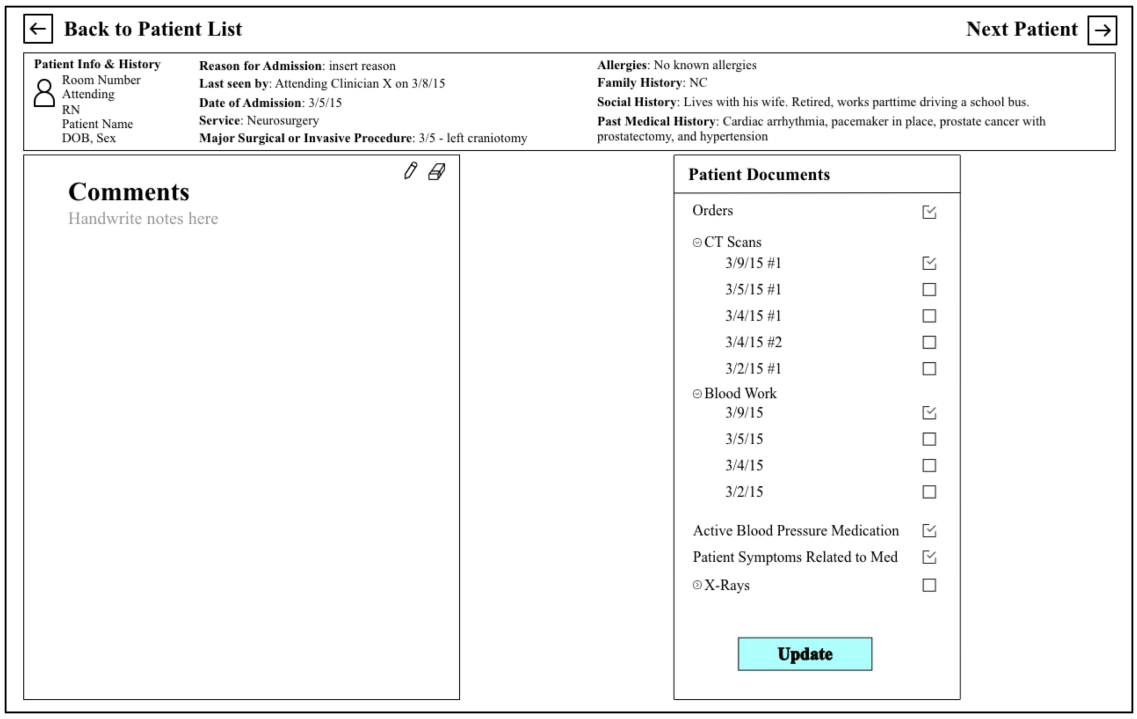
Screen 6: Rounding Page with Handwritten Reminder

After writing a handwritten comment on Screen 6, the comment is automatically translated into text, shown in Screen 7.



Screen 7: Handwritten Reminder Translated into Text

The “Change Information Displayed” button in the bottom right corner of Screen 3 leads to Screen 8. The right side of Screen 8 displays a list of patient documents, so the clinician can manually select documents to be displayed on Screen 3, if the automatically chosen documents are insufficient.



Screen 8: Change Information Displayed

3.2.2 Prototype 2: Feedback

Similar to the interview for Prototype 1, Dr. A was my only interviewee for Prototype 2, so the feedback does not reflect all clinicians' perspectives. This interview was conducted on Skype, so it was necessary for me to be the intermediary between Dr. A and the prototype as we walked through tasks (Appendix B). The feedback highlights high-level and low-level design choices and EHR component visualizations that affect the usability of the EHR interface design. The feedback is summarized by important EHR component.

Timelines

Timelines refer to components that visualize non-numerical information over time. The medication timeline is displayed alone in Prototype 2, but feedback indicates that integrating it with additional patient information would create a more cohesive view of the patient experience. Initial feedback on Prototype 1 suggested that the specific design of a Hospital Course Timeline might be hard to generalize across patients, but that the idea to visualize a patient's upcoming and past schedule across different categories would help clinicians structure the visit (Objective 2). The feature could be brought back in a more generalized format as the patient schedule which would enable clinicians to understand the patient journey. A patient schedule, including medication schedule, procedures, and therapy appointments, combines non-numerical data to visualize the patient's day.

Images

The EHR interface design aims to show, in as few screens as possible, all, and only, the information that the clinician would need during rounds (Objective 2). All features should be accessible from the patient record home screen, but some components require more space to be interpreted. As a result, *CT Scan* and *Blood Results* are previewed in Screen 3, but expand into

their own screens (Screen 5, 6). Prototype 2 shows a thumbnail image of the CT scan on Screen 3 and displays a full size image on Screen 5, if the clinician navigates to that screen. Including thumbnail images, from Dr. A's perspective, is not an effective use of space, since clinicians need to see a larger image to interpret the results. Although the thumbnail image is not an effective way to convey the CT scan results, it could help the clinician if the purpose is to locate results. In this case, design Objective 1 and Objective 3 contradict each other since the thumbnail image inadvertently speeds up the locating process, but duplicates information and uses valuable space.

Graphical Displays

Prototype 2 includes multiple graphs to help clinicians interpret changing information. Dr. A noted that the Blood Results measurements have such small variations and many clinicians have these ranges memorized, so graphs are not an effective way of helping clinicians interpret the changes. There are other, non-graphical representations (e.g., colors, arrows) that might be better suited for certain situations. The choice to include or exclude graphical displays, depending on context of the information will be important in creating an interface that clinicians can quickly use (Objective 1).

Reminders

Reminders, in Prototype 2, allows the clinician to take unstructured notes while he or she is in the room with the patient. Dr. A mentioned that Dr. A normally makes a patient comment or to-do list prior to rounding to bring in the patient room to continue taking notes. Dr. A suggests that this functionality could be replicated in the EHR interface design by pre-populating *Reminders* with notes that the clinician took on patient documents prior to rounding. Although one benefit of *Reminders* is its unstructured nature, Dr. A suggests that organizational features could add optional

structure. *Reminders* helps the clinician by accommodating existing behaviors (Objective 2) and minimizing the note entry work after rounds.

The feedback on Prototype 2 indicates that high-level design choices (e.g., Reminders) facilitate clinician EHR use (Objective 1), because clinicians' existing behaviors are accommodated in the design (Objective 2). The design choices must now be refined to include dynamic visualizations depending on their relevance relative to other components (Objective 3).

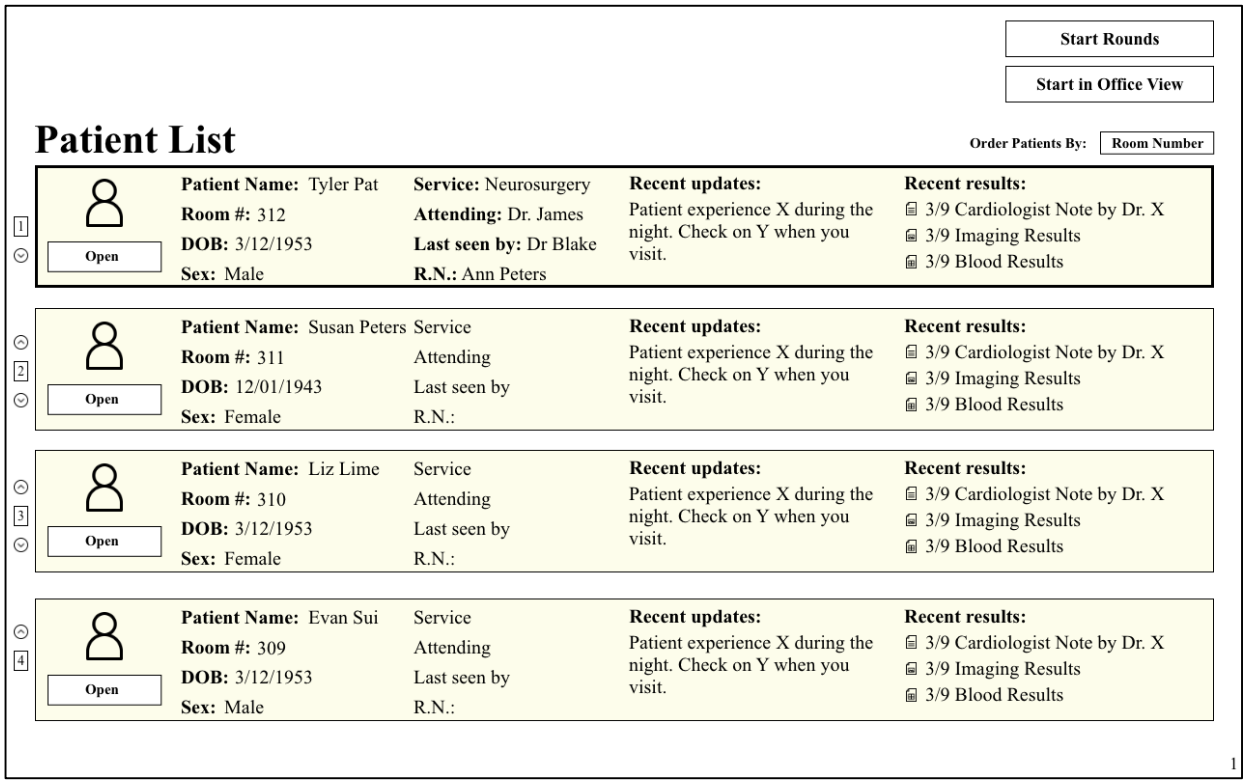
Chapter 4

Final Design

4.1 Design Walkthrough

To understand the workflow and functionality of the EHR interface design for rounding, I will introduce a persona, Dr. James, who will help us navigate through the system in context. Dr. James is spending the morning visiting her patients in their rooms. She started her morning by looking through the EHR system to see what has happened to her patients since her last visit. For each patient, she checked the patient's vital signs, took brief notes on new results, and made a to-do list relating to the patient's care plan. Now, she is about to start rounding to check in with each patient, go over results, and share upcoming events and goals. We will walk through the prototype as if we are with Dr. James while she is in the room with a specific patient.

Dr. James opens the EHR to Screen 1 which displays the list of patients with basic information about their care team, recent results, and recent updates. The information paired with the patient name is selected to remind Dr. James about the patient's history and current health status. Dr. James can also easily open recent results from the patient list. From Screen 1, Dr. James can click "Start Rounds" or "Start in Office View" which result in different visualizations of the same patient record. Dr. James used "Office View" when she was looking over patient information before rounds. Now that she is doing rounds, she can directly "Open" a patient file or she can use "Order Patients by" to choose an order to organize the patients by such as room number, last seen, attending name, or language spoken. Dr. James can also manually organize the patients or switch the ordering using the arrows on the left side of Screen 1.



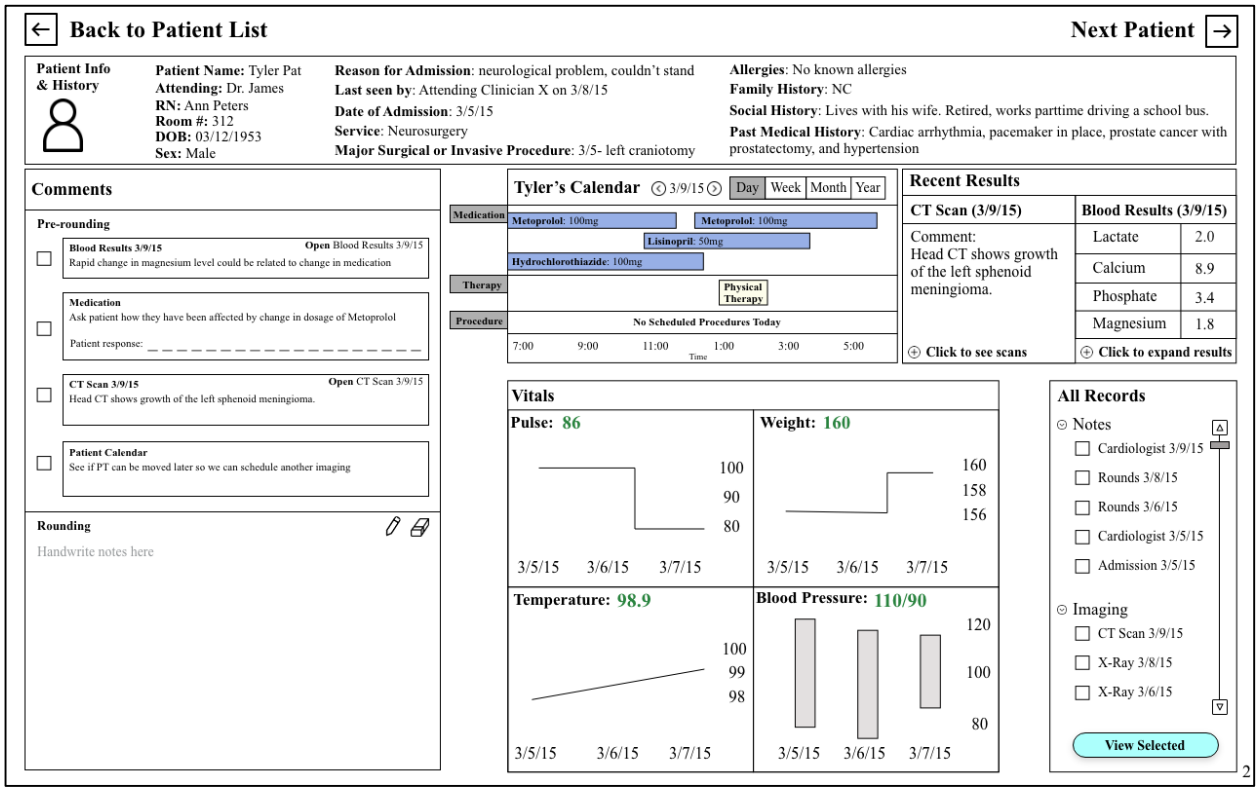
Final Screen 1

After choosing an order, Dr. James selects "Start Rounds" and arrives on the patient record (Screen 2) for Tyler Pat, the first patient on her list. Dr. James can access all EHR features from this page which maximizes time spent focused on the patient (Objective 1). The top part of Screen 2 displays Tyler's background information (e.g., date of birth, reason for admission, and allergies). On the lower right side of Screen 2, *Vitals* displays Tyler's pulse, weight, temperature, and blood pressure in four quadrants. Dr. James can easily see Tyler's most recent vitals, displayed in numerically in green (to indicate that it is in the normal range) and she can also use the graph to see how today's values compare to previous values. This visualization combines graphs with numerical data and visual cues (colors) to help Dr. James quickly interpret information (Objective 1).

Dr. James looks at *Tyler's Calendar*, above *Vitals*, to see any upcoming events for Tyler. This calendar combines different types of events like medicine schedule (including the duration

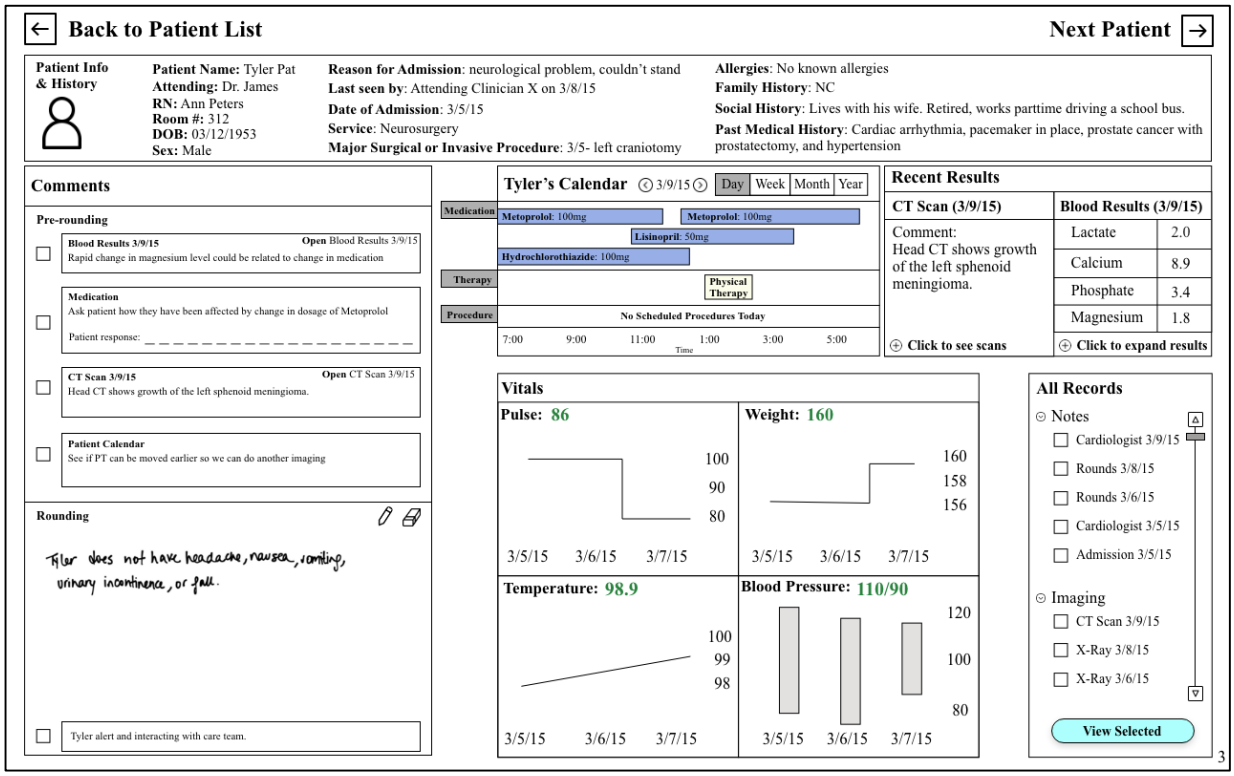
that the medicine is active), procedures, and therapies. The calendar allows the care team and the patient to visualize upcoming events and make plans for the day. Combining the patient medication schedule with other events shows a more complete picture of when the care team will be in contact with Tyler.

Next to *Tyler's Calendar*, Dr. James sees a section called *Recent Results*. *CT Scan (3/9/15)* and *Blood Results (3/9/15)* appear in this section. The information contained in *Recent Results* changes dynamically when new information is added, so only a few documents appear in this section at a time. The information displayed for each document represents a preview of the newest information. The purpose of *Recent Results* is to group together information that clinicians will likely want to see at the same time (Objective 3). For each recent result, Dr. James can select "click to see X" to see a document-specific page with multiple images, results, or notes across different dates.

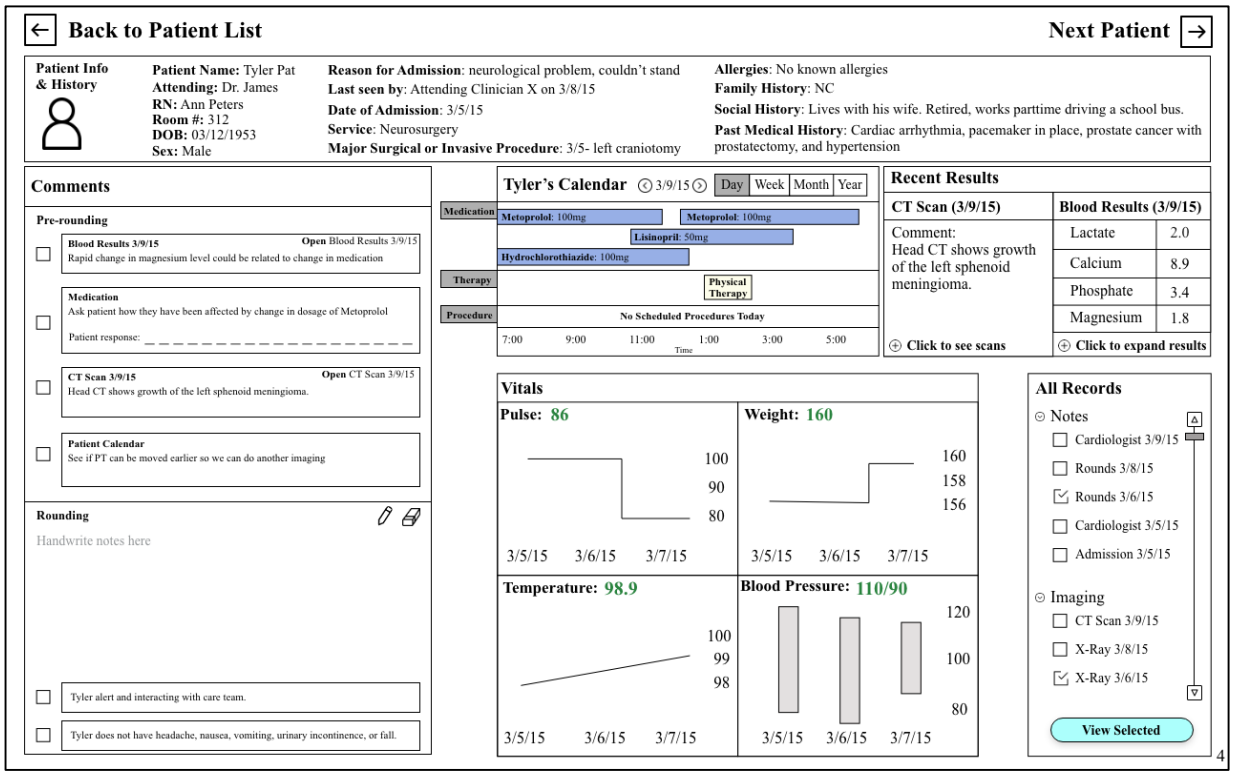


Final Screen 2

On the left side of Screen 2, Dr. James can view her Comments. This section is separated into pre-rounding and rounding comments. The pre-rounding comments were written by Dr. James while she was viewing the patient's file in "Office View" (Objective 2). These comments might be linked to a specific patient document; if this is the case, then the left header for the specific comment will indicate the document on which the comment was made and Dr. James can select "open" to see the comment directly on the document. This EHR interface assumes that the user is using a digital pen to handwrite notes on the page. The system translates the handwriting into text, extracts it from specific documents, and places it in the pre-rounding comments section; this accommodates clinicians' natural behavior of handwriting notes (Objective 2), but also considers the system's need for structured input from rounds. The items written in the Rounding section are also automatically transformed from handwriting to text and are placed under the previous comment at the bottom of the section, so as not to disrupt the note-taking process (Objective 1).

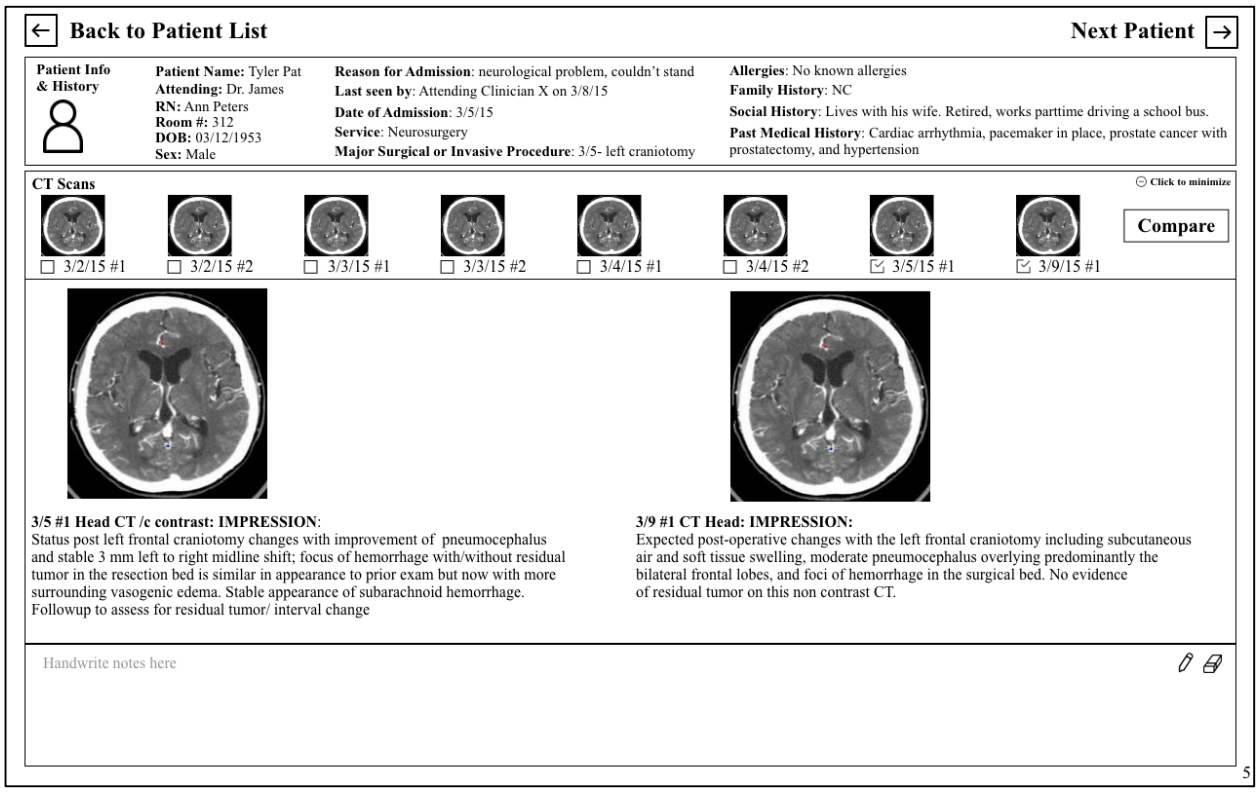


Final Screen 3



Final Screen 4

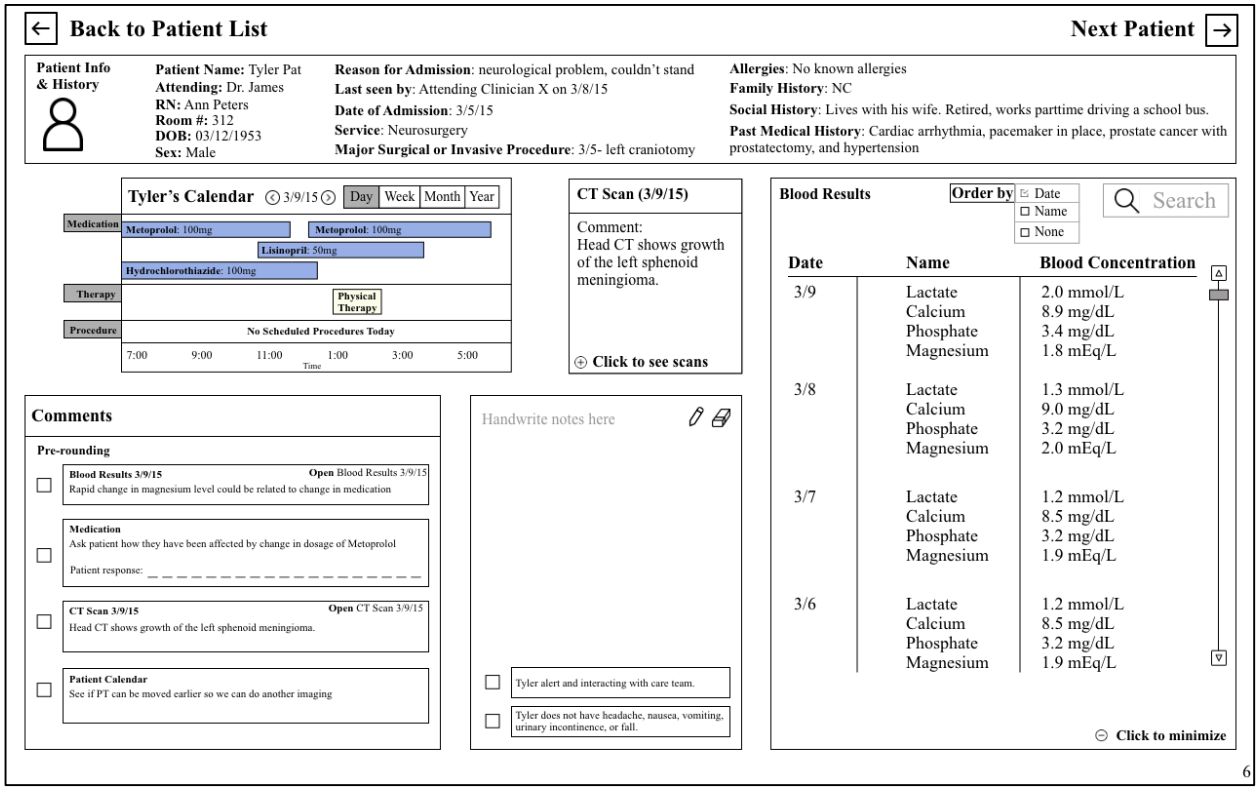
In the CT Scan example in *Recent Results*, Dr. James must "click to see" the CT Scan images. In this scenario, *Recent Results* indicates that there are new CT Scans to view, without showing a preview image, and Dr. James can click to see the recent CT Scan as well as past scans, if she chooses (Screen 5). This CT Scan comparison easily displays scans which might reveal information about the most recent results (Objective 3).



Final Screen 5

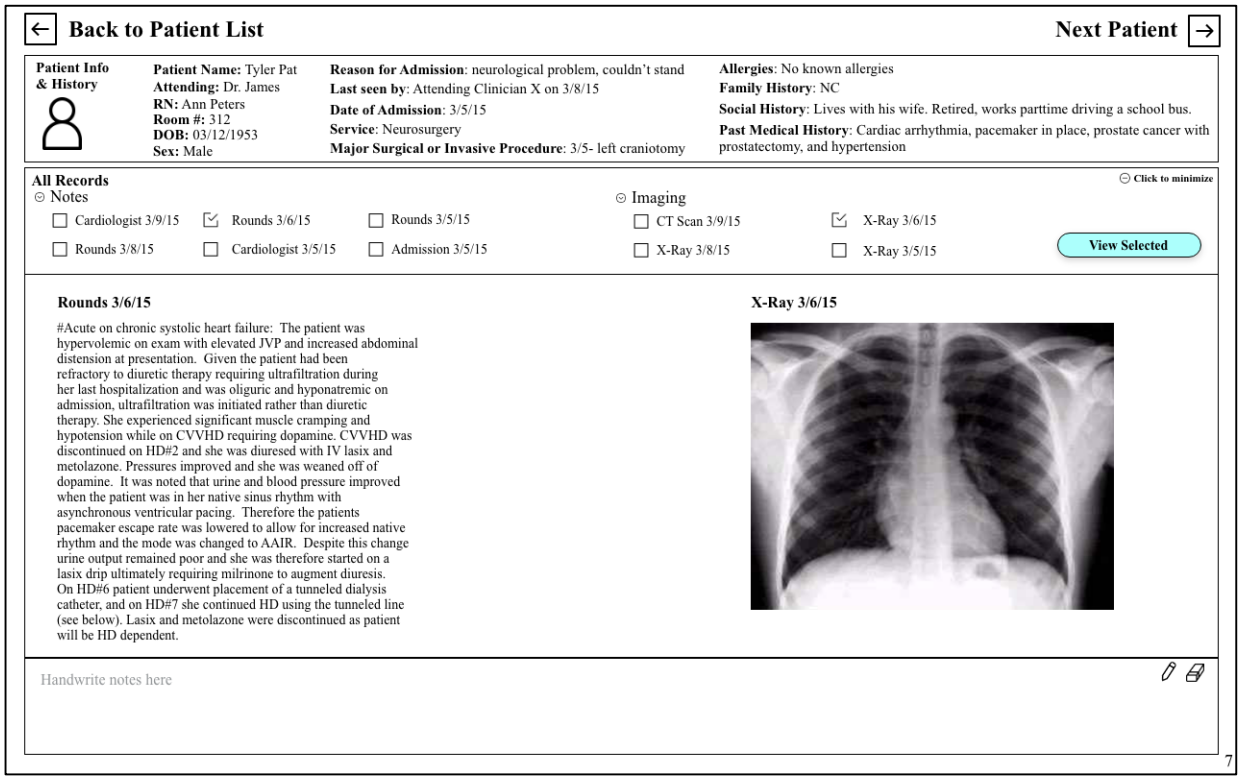
In the Blood Results example in *Recent Results*, only the most recent test results are displayed on Page 2 (Objective 2), but if Dr. James wants to compare the values to previous days, she can "click to expand results" to see current and previous values (Screen 6). Now, Dr. James has the option of looking at blood results across different days. She is able to filter the results and search for specific dates or measurements. This comparison feature expands within the primary page (Screen 4) instead of opening in a new window. This expansion decreases the number of clicks that Dr. James needs to get from one function to the next and increases engagement with the

patient, because she can compare the Blood Results and then select another component from that screen.

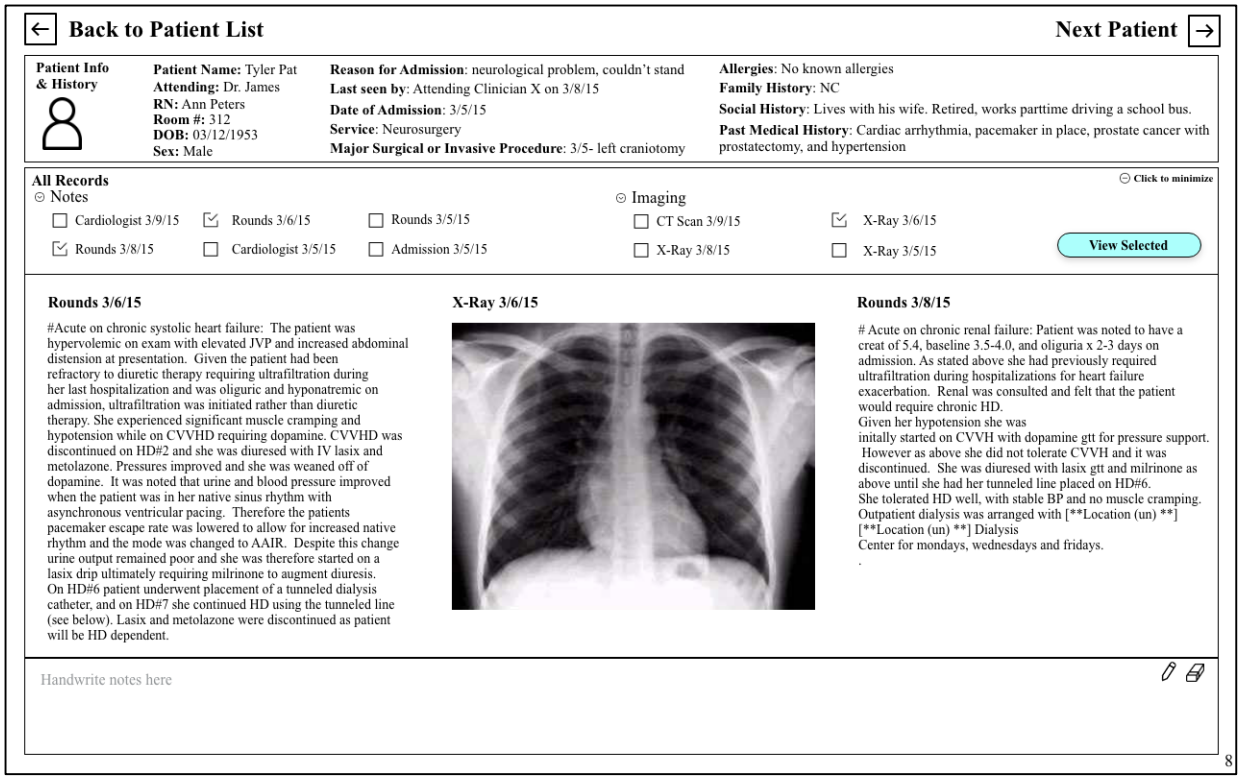


Final Screen 6

All Records, initially displayed on Screen 2, contains all the past clinical, nursing, and consultant notes, imaging results, and lab results, organized by record type. If Dr. James wants to see any number of Tyler's records, she can simply select the desired ones and click "view selected." This opens a new page where she can see the records side by side and take notes on this page or on the records themselves (Screen 7).



Final Screen 7



Final Screen 8

4.2 Final Design Feedback

I conducted three final evaluation interviews, all of which lasted between 30 and 45 minutes. Dr. B was the first interview, Dr. C was the second interview, and Dr. D and E were interviewed together in the third interview. I refer to all interviewees as Dr. X to preserve their anonymity**,** although one interviewee was still in medical school. Each interviewee has varying experience using EHRs in an inpatient setting; some use it daily in their interactions with patients, while others used it during their residency, or have only used it in a learning capacity. I asked the interviewees to use the prototype to try to accomplish different tasks (Appendix B). I asked the interviewees questions about the design choices throughout the interaction and asked for their overall impression and feedback on the design after completing all the tasks.

The feedback relating to graphical displays, comments (previously reminders), and the document comparison functionality highlight the design choices that work to achieve the design objectives. Future iterations of these components will contribute to improving the clinician's rounding experience. I explain the principles and considerations that make these effective choices for maximizing clinician engagement with the patient, accommodating clinicians' behaviors and actions, and integrating information dynamically.

Graphical Displays

Although graphical displays often make numerical data easier to interpret, they also attract attention and require more space to convey information. To highlight only the most relevant information in the record, not everything that can be displayed as a graph should be; the presence of a graph should signify to the clinician that there is something noteworthy to discover.

This claim is supported by feedback on *Vitals*. Dr. B said that the vitals are the first thing that the clinician would want to see, but he or she only needs to notice the abnormal values. Dr. B

suggested positioning *Vitals* in the top left corner (where eyes naturally wander first) or highlighting *Vitals* with color to attract the clinician's attention without taking up too much space. Dr. D suggests only automatically displaying the graphs for abnormal values in *Vitals* and simply displaying the number for normal values. These suggestions highlight the benefit of using graphical displays to alert clinicians to pertinent information.

Additionally, graphs are not always the most effective way to highlight changes in numerical data. Numerical data impedes clinicians' ability to quickly interpret results, but additional visual cues can help convey information without being displayed as prominently as graphs. For blood results, visual cues could be distinct colors or exclamation marks (to signal abnormal values) or arrows (to show direction of change). These provide hints for clinicians to interpret changing values (Objective 3). Non-numerical data, such as the medication list, could use visual cues to convey information about when the medication was prescribed, as suggested by Dr. E.

Comments

Comments supports clinicians' natural, unstructured note taking process during rounds, but needs a consistent placement across EHR screens to focus clinicians' attention on the patient and not the location of the notes.

Dr. B and Dr. D liked how *Comments* functions as a to-do list and incorporates notes taken before rounds, respectively. Both of these comments emphasize *Comments'* accommodation of clinicians' natural behaviors through its functionality (Objective 2), however, Dr. B and Dr. E suggested relocating and consistently placing *Comments* to create stability that would ultimately help the clinician focus on the patient. The location of *Comments* within the screen must consider its relation to other components.

Document Comparison

The document comparison functionality, for *CT Scans* (Screen 5) and *All Records* (Screen 8), facilitates custom document section to accommodate clinicians' proclivity for synthesis. All interviewees enjoyed these features for their flexibility. The document comparison functionality directly responds to Objective 2, because the design helps integrate separate information. Opening multiple documents in the same screen can also help clinicians create a map of the patient's experience.

The feedback suggests that the individual design of the components considers visualization techniques and functionality that make the components easy to interpret and use, but that the cohesion of the components must be improved to purposefully guide the clinician through the information on the screen. Through this cohesion, which considers the order in which components should be viewed and the relative importance of each result, the design will help clinicians use the EHR screen to easily extract information, quickly record information, and thoughtfully engage with the patient.

Chapter 5

Discussion and Limitations

The feedback on the final design highlights specific successes and failures of the EHR interface design that influence how clinicians are able to engage with patients and retain information. The entire design process helped identify specific components and design choices that can improve the clinician experience during rounds, however, there are several limitations to this project. The prototypes relied on anonymized patient data, but this data was a summary at discharge rather than individual documents collected over the course of the patient's stay. As a result, the prototypes did not contain as much data as would actually be contained in a patient's file. This sparseness of data made it harder for users to imagine how the EHR interface would translate to their own patients. Although this thesis was based on a qualitative study in which the researchers watched clinicians use EHRs, I did not participate in this study, so I was unable to directly observe the clinicians. As a result, my insights are based on second-hand experience. Despite these limitations, the thesis still presents high-level principles that can be applied to EHR interface design across departments. These principles and considerations account for general clinician workflow, supported by studies and feedback on Prototypes, which can be refined in future design iterations.

Chapter 6

Conclusions and Future Research

This thesis aimed to design an EHR interface for rounding that maximizes clinicians' engagement with the patient, accommodates clinicians' natural behaviors and actions, and helps clinicians interpret information by integrating traditionally separate components.

Throughout the design process, I identified three component design choices that should be included in an EHR interface design to achieve the design objectives. These components are the graphical displays, comments sections, and document comparison functionality. The comments section helps clinicians naturally capture critical patient information without preemptively imposing structure on the notes (Objective 2). The document comparison functionality and graphical displays both convey and combine information to help clinicians easily understand a patient's experience (Objective 3). In future design iterations, these design features can create an interface that maximizes the clinician's engagement with the patient (Objective 1) by considering how the components should fit together based on the relative importance and flow of information.

This thesis shows several design components that move towards realizing the design objectives, however, there is still much to be done to create an EHR interface design that will fundamentally change and improve clinicians' rounding experience. The next step would be to redesign the interface based on the feedback on the final design. This iteration would focus on the dynamic visualization of components and could also include patient-facing elements, so that the clinician could use the EHR as an educational tool with the patient. Further improvements could

work to expedite formal note taking processes after rounding. As evidenced by ongoing and past research, EHRs can be improved in many ways to fit into clinicians' workflow before, during, and after rounds. Any future research that occurs must consider how to create a system that augments the clinicians' ability to interact with and care for their patients without overburdening them with data.

Appendix

Appendix A

Interview Guide

The goal of this project is to design an EHR interface that will support clinicians' workflow in the inpatient setting during morning rounds. In preparation for this interview and as a part of the design process, I have spent time reviewing literature on existing usability problems in EHRs. I have discussed findings from Shiri Assis-Hassid's qualitative study at BWH and I have prepared initial designs of information that might be useful to have in an EHR while doing rounds. By understanding the goals of the clinician and the existing problems clinicians encounter in EHRs, I want to work towards creating a design that does not overburden the clinician while they are in the room and instead allows them to easily access relevant information. At this point in the process, I want to speak to you, as a clinician, to get a first hand understanding of how you prepare for and conduct morning rounds. Additionally, I would like to get your feedback on my initial design ideas. This information and feedback will help me ground my future designs in insights that will allow me to design for the clinician in this specific context.

I would like to use your experience to influence the design of an EHR interface that would help clinicians easily review patient information in real time, and make decisions pertaining to the patient's plan of care. I would like to use visualization and summarization techniques to transform a patient record into a clinician-friendly dashboard. At the end of the interview, I'd like to share some ideas with you and would like your feedback. Can I ask for your permission to record this interview? Before we get into discussing any EHR systems, I would like to get a general sense, without relation to the EHR, of how you work.

Question	Prompts

1) Can you walk me through your workflow? Starting from when you begin your rounds, and including your interaction with a patient and everything that follows that interaction.	What decisions do you make during the encounter? What do you need to accomplish?

Workflow & Patient Record

Question	Prompts
2) What information do you bring with you to the encounter?	i.e., notes about suggested plan of action? Patient lab results? Info about patient?
3) If you take notes before meeting with the patient, how do you do so?	i.e., do you take notes by hand?
4) As you are meeting / discussing with the patient, what information do you refer to?	i.e., patient history? Drug interactions/side effects?
5) If handwriting is used for note taking: What types of information do you handwrite?	
6) How do you keep track of/stay updated on: special events, tasks that need to be carried out regarding the patient?	i.e., do you use a special calendar? Special events = upcoming surgeries, etc.
7) Is there any information in the patient record that is unnecessary to see while you are in the patient's room?	I noticed while looking through patient records that info like family history always appears – curious how often certain info is used.

System Ideas

Questions
8) Which features of the proposed interface do you like/find useful?
9) Which features would not be helpful/would you not use and why?
10) Are there changes that can be made to the helpful or unhelpful features that would make them more useful/easier to user?

General Ideas & Feedback

Question
11) Do you have ideas for things you would like to see in the system interface?
12) Anything else you think would be helpful for me to know when designing this interface?

Appendix B

Tasks

You are a clinician doing rounds and are currently in patient X's room…

- Open a patient's record.
- Compare their blood magnesium level to the previous week's and write down any comments.
- Open Rounds 3/6/15 and X-Ray 3/6/15.
- Write a comment.
- Compare recent CT Scan to past CT Scans.

Bibliography

[1] Bates, D. W., Ebell, M., Gotlieb, E., Zapp, J., & Mullins, H. C. (2003). A proposal for electronic medical records in U.S. primary care. *Journal of the American Medical Informatics Association, 10*(1), 1-10. doi:10.1197/jamia.M1097

[2] Mennemeyer, S. T., Menachemi, N., Rahurkar, S., & Ford, E. W. (2016). Impact of the HITECH act on physicians' adoption of electronic health records. *Journal of the American Medical Informatics Association : JAMIA, 23*(2), 375-379. doi:10.1093/jamia/ocv103

[3] Embi, P. J., Yackel, T. R., Logan, J. R., & Bowen, J. L. (2004). Impacts of computerized physician documentation in a teaching hospital: Perceptions of faculty and resident physicians. *Journal of the American Medical Informatics Association, 11*(4), 300-309. doi:10.1197/jamia.M1525

[4] Park, S. Y., Lee, S. Y., & Chen, Y. (2012). The effects of EMR deployment on doctors' work practices: A qualitative study in the emergency department of a teaching hospital. *International Journal of Medical Informatics, 81*(3), 204-217. doi:10.1016/j.ijmedinf.2011.12.001

[5] Varpio, L., Day, K., Elliot-Miller, P., King, J. W., Kuziemsky, C., Parush, A., . . . Rashotte, J. (2015). The impact of adopting EHRs: How losing connectivity affects clinical reasoning. *Medical Education, 49*(5), 476-486. doi:10.1111/medu.12665

[6] Saleem, J. J., Russ, A. L., Neddo, A., Blades, P. T., Doebbeling, B. N., & Foresman, B. H. (2011). Paper persistence, workarounds, and communication breakdowns in computerized consultation management. *International Journal of Medical Informatics, 80*(7), 466-479. doi:10.1016/j.ijmedinf.2011.03.016

[7] Nuss, M. A., Hill, J. R., Cervero, R. M., Gaines, J. K., & Middendorf, B. F. (2014). Real-time use of the iPad by third-year medical students for clinical decision support and learning: A mixed methods study. *Journal of Community Hospital Internal Medicine Perspectives, 4*(4), 1-7. doi:10.3402/jchimp.v4.25184

[8] Lin, C., & Gennari, J. H. (2011). Understanding the work of pediatric inpatient medicine teams: Implications for information system requirements. *AMIA ... Annual Symposium Proceedings / AMIA Symposium. AMIA Symposium, 2011*, 455. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/22195099

[9] Collins, S. A., Gazarian, P., Stade, D., McNally, K., Morrison, C., Ohashi, K., . . . Dykes, P. C. (2014). Clinical workflow observations to identify opportunities for nurse, physicians and patients to share a patient-centered plan of care. *AMIA ... Annual Symposium Proceedings / AMIA Symposium. AMIA Symposium, 2014*, 414. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/25954345

[10] Aggarwal, C. C. (2012). *Mining text data*. New York [u.a.]: Springer.

[11] Pivovarov, R., & Elhadad, N. (2015). Automated methods for the summarization of electronic health records. *Journal of the American Medical Informatics Association, 22*(5), 938-947. doi:10.1093/jamia/ocv032

[12] Kayi, E. S., Yadav, K., Chamberlain, J. M., Choi, H. (2017). Topic Modeling for Classification of Clinical Reports. arXiv: 1706.06177.

[13] Cohen R, Aviram I, Elhadad M, Elhadad N (2014) Redundancy-Aware Topic Modeling for Patient Record Notes. PLoS ONE 9(2): e87555. doi:10.1371/journal.pone.0087555

[14] Hirsch, J. S., Tanenbaum, J. S., Lipsky Gorman, S., Liu, C., Schmitz, E., Hashorva, D., . . . Elhadad, N. (2015). HARVEST, a longitudinal patient record summarizer. *Journal of the American Medical Informatics Association, 22*(2), 263-274. doi:10.1136/amiajnl-2014-002945

[15] Roman, L. C., Ancker, J. S., Johnson, S. B., & Senathirajah, Y. (2017). Navigation in the electronic health record: A review of the safety and usability literature. *Journal of Biomedical Informatics, 67*, 69-79. doi:10.1016/j.jbi.2017.01.005

[16] Senathirajah, Y., Bakken, S., & Kaufman, D. (2014). The clinician in the driver's seat: Part 1 - a drag/drop user-composable electronic health record platform. *Journal of Biomedical Informatics, 52*, 165. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/25240253

[17] Henry, J., Pylypchuk, Y., & Searcy, T. (2016). Adoption of Electronic Health Record Systems among U.S. Non-Federal Acute Care Hospitals: 2008-2015. *ONC Data Brief,* 35. Retrieved from https://dashboard.healthit.gov/evaluations/data-briefs/non-federal-acute-care-hospital-ehr-adoption-2008-2015.php

[18] Unni, P., et al. (2016). Why aren't they happy? An analysis of end-user satisfaction with Electronic health records. *AMIA Annu Symp Proc*. 2016, 2026-2035.

[19] Middleton, B., et al. (2013). Enhancing patient safety and quality of care by improving the usability of electronic health record systems: recommendations from AMIA. *J Am Med Inform Assoc, 20.* doi: 10.1136/amiajnl-2012-001458.

[20] The Field Guide to Human-Centered Design. Ideo.org.

[21] *MIMIC-III, a freely accessible critical care database. Johnson AEW, Pollard TJ, Shen L, Lehman L, Feng M, Ghassemi M, Moody B, Szolovits P, Celi LA, and Mark RG. Scientific Data (2016). DOI: 10.1038/sdata.2016.35*. Available from: http://www.nature.com/articles/sdata201635

[22] Design Methods Needfinding, *Hasso Plattner Institue of Design at Stanford.* http://hci.stanford.edu/courses/dsummer/handouts/NeedFinding.pdf

[23] Elhadad, N., McKeown, K., Kaufman, D., & Jordan, D. (2005). Facilitating physicians' access to information via tailored text summarization. *AMIA ... Annual Symposium Proceedings / AMIA Symposium. AMIA Symposium,* 226. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/16779035

[24] Assis-Hassid, S., Grosz, B.J., Zimlichman, E., Rozenblum, R., Bates, D.W. (2018). Integration of EHRs into Inpatient Care: A qualitative evaluation, *JHM (in press).*