ELECTRONIC PRESCRIBING SYSTEM USER INTERFACE DESIGN AND PRESCRIBING ACCURACY

INVESTIGATING THE IMPACT OF ELECTRONIC PRESCRIBING SYSTEM USER INTERFACE DESIGN ON PRESCRIBING ACCURACY

By

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A Thesis
Submitted to the School of Graduate Studies
in Partial Fulfilment of the Requirements for the Degree
Master of Science

McMaster University

MASTER OF SCIENCE (2014) McMaster University
Health Research Methodology Hamilton, Ontario

TITLE: Investigating the impact of electronic prescribing system user interface design on prescribing accuracy

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NUMBER OF PAGES: ix, 115

Abstract

Background: Electronic prescribing systems are designed to aid in the complex process of prescribing by providing patient information and decision support at the point of care. Successful implementation and effectiveness depend on a variety of factors, including usability and user interface design, which influence how the information and decision support are relayed to users. Poorly designed systems have been found to be associated with medication errors.

Methods: We conducted a factorial design study to investigate the impact of screen density, highlighting, and placement of information, on the accuracy of prescribing when using an e-prescribing system. Study sessions were held during clinical pharmacology educational rounds, where residents and medical students answered simulated prescribing scenarios presented on various e-prescribing system interface configurations. Assignment of prescribing scenarios to interface configurations and presentation order were randomized between study sessions. Participants were also asked about their preferences for specific user interface configurations.

Results: A total of 66 participants completed 844 prescribing cases, with 583 (69%) cases answered correctly. The presence of highlighting was associated with correct prescribing decisions (p-value = 0.001), with 181 out of 250 (72.4%) prescribing scenarios answered correctly on interfaces with highlighting of key clinical information, as opposed to 156 out of 242 (64.5%) on interface configurations without. Low screen density and central placement of information were not found to be statistically significant predictors of prescribing accuracy. The presence of highlighting was the only factor that the majority of participants (80.3%) preferred, but no effect was found when comparing prescribing accuracy on preferred versus non-preferred interface configurations.

Conclusions: The factorial design methodology developed is a novel approach for efficient and objective evaluation of multiple user interface design factors in one study. Evidence-based design and usability principles are needed to enhance the design and appropriate use of e-prescribing systems as usability problems continue to be one of the primary reasons for dissatisfaction and poor levels of adoption.

Acknowledgements

I wish to thank and acknowledge everyone who has contributed towards this research project and provided support throughout that made completing this thesis possible. First and foremost, I wish to thank my graduate studies supervisor, Dr. Anne Holbrook, for your guidance, teaching, and continuous support. I appreciate the wealth of knowledge you have passed on and the many lessons learned, including always stressing the importance of rigour in designing and conducting research studies. I would like to thank my thesis committee members, Dr. Eleanor Pullenayegum and Dr. Ann McKibbon for always being available to answer questions, providing helpful insight and suggestions on methodology, along with steady encouragement. Thank you also to Dr. Edward Etchells for providing the external review and constructive commentary, and sharing your expertise in this field.

This research project also benefitted from the contributions of a number of individuals, from conception to completion. I would like to thank Dr. Karim Keshavjee and Dr. David Chan for providing valuable input and information about e-prescribing systems and the current state of the field. I also thank Dr. Per Vandvik and Dr. Zardasht Gaf for helping to pilot the study methodology, and Kaitryn Campbell and Nancy Santesso for suggestions and help on developing the literature search strategies.

Working with the research community at the Department of Clinical Epidemiology and Biostatistics was an exceptional experience, providing me with the foundation for a career in health research. For this I thank the individuals mentioned above and the many others who I have had the opportunity to work with, as well as the

support staff at the department and at the Centre for Evaluation of Medicines. I'd also like to give a special thank you to Sue Troyan for your friendship and lasting support.

Finally, I thank my family and friends for their unwavering supporting and encouragement.

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List of Abbreviations

AHRQ	Agency for Healthcare Research and Quality
ALT	Alanine transaminase
ASA	Acetylsalicylic acid
AST	Aspartate aminotransferase
BID	Twice daily
CDSS	Computerized decision support system
CHF	Congestive heart failure
COPD	Chronic obstructive pulmonary disease
CPOE	Computerized physician order entry
DI	Drug interaction
D.O.E.	Design of experiment
Dx	Diagnosis
eGFR	Estimated glomerular filtration rate
e-prescribing	Electronic prescribing
GEE	Generalized estimating equation
HbA1c	Hemoglobin A1c
HDL	High-density lipoprotein
HGH	Hamilton General Hospital
HIMSS	Healthcare Information and Management Systems Society
INR	International normalized ratio
ISO	International Organization for Standardization
IU	International units
LDL	Low-density lipoprotein
LFT	Liver function test
MeSH	Medical subject heading
MFP	McMaster Family Practice
MI	Myocardial infarction
MUMC	McMaster University Medical Centre
NIST	National Institute of Standards and Technology
OD	Once daily
QID	Four times a day
RCT	Randomized controlled trial
SFHC	Stonechurch Family Health Centre
SJH	St. Joseph's Healthcare Hamilton
UTI	Urinary tract infection

1.0 Background

1.1 Electronic Prescribing Systems

The process of prescribing medications can be complex and is prone to error, with resulting implications for patient safety. Preventable drug-related morbidity due to inappropriate prescribing is a significant problem in the Canadian healthcare system. It has been estimated that the incidence rate of adverse events during hospital admissions in Canada is 7.5%, with about 40% of the events deemed as preventable, with adverse events due to drugs and fluids being the second most common type after surgical adverse events.[1] Medication errors, adverse drug events, and failure to prescribe beneficial medications are a threat to patient safety and result in considerable costs for healthcare systems.[2-4] Information on patient history, allergies, past and current medications, key laboratory results and current best evidence is critical to clinicians prescribing the appropriate medications, but is frequently not available at the point of care.[5] This lack of information is often the cause of prescribing errors and results in patients being harmed by inappropriate medications or not being prescribed beneficial medications.[6-9]

Electronic prescribing (e-prescribing) systems that provide computerized decision support to clinicians at the point of care are designed to aid in the complex process of prescribing.[10] E-prescribing refers to the use of computers to create, modify, review, and dispense prescriptions. The systems can provide clinicians with vital patient information and decision support to improve their prescribing.[11] E-prescribing systems may have functional capabilities to provide basic decision support, such as drug-allergy checking, guidelines for dosing, and drug-drug interaction checking, as well as advanced decision support, such as guidelines for drug-related laboratory tests. The systems are particularly useful in the technical aspects of prescribing appropriate medications, through functions

such as calculating dosage or identifying drug interactions. Similarly, e-prescribing systems can aid in the consideration of societal implications, through functions such as drug formulary alerts. Consequently, organizations such as Canada Health Infoway are advocating system-wide implementation of e-prescribing technology across Canada, with presumptions that the systems will decrease adverse drug events and improve prescribing practice.[12]

1.2 Implementation and Adoption of Electronic Prescribing Systems

The successful implementation and effectiveness of an e-prescribing system depends on a variety of factors such as technical capabilities, the quality of decision support, and usability of the system.[13,14] Barriers to adoption include changes in clinical workflow, acceptability, readiness, costs of implementation, technical barriers (e.g. bandwidth and internet access), legislative barriers and social and ethical barriers (e.g. confidentiality, privacy).[15-17] In moving forward with the implementation of e-prescribing systems, it is also important to identify factors for successful implementation and uptake of these systems. In addition to factors such as technical functionality, standards, and costs, usability is one of the most important factors for optimal adoption and effectiveness of e-prescribing systems.

E-prescribing systems maintain a number of functional capabilities intended to allow prescribing and to support decision making, including patient demographic information, medication selection menus, lab information, dosage calculation, safety alerts, and formulary alerts.[18] For these features to work as intended and be beneficial to the user, they must be presented in a way that is user-friendly and ensures accuracy of prescribing decisions. The design and content of the user interface of an e-prescribing

system directly relates to the usability of the system. Research in this area is lacking, specifically in regard to usability and user interface design of e-prescribing systems. Identifying and evaluating user interface design factors that may impact the accuracy of prescribing will ultimately help enhance the design and appropriate use of e-prescribing systems and the likelihood of their successful adoption.

1.3 Evaluation of Electronic Prescribing Systems

Computerized prescribing systems that provide prescribing decision support at the point of care are a relatively new technology. The effectiveness of these systems on patient outcomes has not yet been widely researched in various clinical settings. Current research projects are focusing on evaluating the effectiveness of these systems in terms of potential benefits for reducing prescribing errors, enhancing patient safety, improving efficiency, and improving adherence to prescribing guidelines. The majority of this current research has focused on the inpatient setting at hospitals, and little research has been done to evaluate the effectiveness of electronic prescribing systems in the outpatient setting, such as primary care practices.[19-25] While viewed as promising innovations with potential to improve prescribing, no high-quality evidence supports that important patient outcomes are improved, especially in Canadian outpatient settings.[26-29]

Despite perceived benefits and potential for improved care, rigorous evaluation of e-prescribing systems is required. In fact, poorly designed systems can have unintended consequences, including increasing medication errors.[30-34] Randomized controlled trials (RCTs) are required for overall evaluation of the effectiveness and safety of the systems, as are studies for evaluation of the components or factors for successful implementation, such as usability. In addition to issues in implementation such as data quality and quality

of the knowledge base for decision support, human factors issues such as usability remain at the forefront.

1.4 E-Prescribing System Usability and User Interface Design

Various standard definitions of system usability have been described. The International Organization for Standardization (ISO) defines usability as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use."[35] Usability has also been broadly defined as "the capacity of a system to allow users to carry out their tasks safely, effectively, efficiently, and enjoyably."[36] Finally, five attributes of usability have been proposed, which include learnability, efficiency, memorability, errors, and satisfaction.[37] For e-prescribing system features to be beneficial to the user and work as intended, they should be presented in a way that conforms to usability guidelines and user interface design principles.[38,39] User interfaces facilitate data input, browsing, editing, and output. A good interface design will encourage easy, natural, and engaging interaction and allow a user to carry out their prescribing tasks successfully.[40-42]

As introduced above, e-prescribing systems maintain a number of functional capabilities to support and allow prescribing, which may include patient selection and demographics menus, diagnosis selection menus, medication selection menus, lab information, safety alerts (drug interaction, allergy, contraindications), formulary alerts, and dosage calculation. Each of these features can play an important role in the process of prescribing and may have an impact on prescribing appropriateness and accuracy when using the electronic prescribing system.[43,44] User interface design features such as screen layout, density of information, position of messages on the screen, and use of colour are

directly related to the usability of an e-prescribing system and usability problems have been previously found to be associated with medication errors.[38,43,45,46]

Usability and user interface design factors will affect whether physicians receive information and decision support as intended in the design of these systems and will also influence physicians' understanding and uptake of information. It is necessary to find out what factors will make e-prescribing systems more user friendly, and to specifically determine whether physicians will receive information and decision support accurately through the design of these systems.

1.5 Usability and User Interface Design Evaluation

The design and content of the user interface of an e-prescribing system directly relate to the usability of the system. Well-designed e-prescribing systems that follow usability principles will likely reduce training time, the learning curve, and the potential for errors to be made, thereby avoiding possible unintended consequences of the e-prescribing system.[31-33,47] Identifying and evaluating user interface design factors that may impact the accuracy of prescribing will ultimately help enhance the design and appropriate use of e-prescribing systems and the likelihood of successful adoption.

Usability and user interface design evaluation has been well covered in computer science and engineering literature as it relates to computer systems, but less attention has been given to it in healthcare with a dearth of high-quality usability research specific to e-prescribing systems.[36,48-51] In healthcare, usability evaluation is often an overlooked, intermediate aspect in the evaluation of the effectiveness of e-prescribing systems and other eHealth technologies, but usability is at least one important determinant of whether e-prescribing systems will be used successfully and improve outcomes.[39,52]

A number of methods for evaluation of computer system usability have been established. Usability testing can be a part of the formative evaluation of systems during the design process (with the objective of improving the design and deployment of the system), and can also be applied as part of the summative evaluation of systems (with the objective of assessing how completed systems meet pre-defined goals regarding issues of functionality, safety, and impact on usability outcome measures).[50] Usability testing methods can be expert-based, involving a usability or human factors expert to conduct a usability assessment or walkthrough of the system, or user-based, involving end users in evaluation of a system.[53]

Expert-based methods include usability inspection methods such as the heuristic evaluation, which involves inspecting a system and comparing the user interface against a list of recognized usability heuristics, and cognitive walkthrough, which involves structured inspection of the steps required to perform a task using the system.[49,53-56] Commonly applied usability heuristics include those proposed by Nielsen,[57] which include 10 heuristics for good user interface design (e.g. flexibility and efficiency of use, match between system and the real world, aesthetic and minimalist design, etc.), those proposed by Shneiderman,[58] which include 8 rules for user interface design (e.g. strive for consistency, permit easy reversal of actions, etc.), and a set of 14 heuristics adapted from Neilsen and Shneiderman by Zhang et al. for the evaluation of medical devices.[59]

User-based evaluations methods include think-aloud,[60] where a user talks aloud while using the system and allows for their though process to be recorded, and simulations (e.g. in the clinical or a usability laboratory setting), where a user performs a specific task and is observed and may have their performance measured.[48,61] User-based

methods may involve measurement of both subjective and objective outcomes, and incorporate the use of surveys to gather information about the user's perspective and outcomes such as user satisfaction. Several surveys have been developed to measure subjective outcomes, including the System Usability Scale (SUS),[62] the Questionnaire for User Interaction Satisfaction (QUIS),[63] and IBM Computer Usability Satisfaction Questionnaires.[64] These usability testing methods can also categorized as direct methods (e.g. thinking aloud, question asking, and performance measurement) and indirect methods (e.g. questionnaires and interviews, observation and ethnographic study, focus groups, self-reporting logs).[65]

Multiple approaches to usability testing may be used in a complementary fashion to exploit the advantages of each method and obtain an in-depth understanding of users' performance and how a system is used.[66,67] Determining what are the most important factors that impact usability will ultimately help enhance physicians' appropriate use of e-prescribing systems and likelihood of successful implementation. Good system usability is likely to influence physician behavior through appropriate use of decision support, and patient outcomes through appropriate prescribing. Given the cost and potential harms of widely implementing e-prescribing systems that may not be optimized for users and patient safety, it is important to undertake an investigation of the factors that will improve system design and usability and, consequently, the accuracy and appropriateness of prescribing when using an e-prescribing system.

1.6 Evaluation of User Interface Design Factors Described in the Literature

Various principles have been proposed for good usability and user interface design. We reviewed literature describing key usability and user interface design

principles, including their applicability in the healthcare setting, with the aim of identifying key design factors or features that may influence the successful use of e-prescribing systems. We identified in the literature two systematic reviews and one targeted reviews of computerized physician order entry (CPOE) and e-prescribing system design and reviewed a sample of usability evaluation studies for various types of systems.

Systematic reviews by Khajouei and Jaspers[38] and Alexander and Staggers[45] as well as a targeted review by Horsky et al.[68] demonstrate that the majority of usability evaluations of CPOE and e-prescribing systems apply traditional usability evaluation methods with clinician participants including think-aloud, observation, user interviews, and simulations in a laboratory setting to identify usability problems. Some noted desirable system design attributes include grouping of related data items (for perceptual judgements), visual cues, consistent terminology, appropriate density of information on the screen, appropriate list lengths, clearly legible font, different font format to emphasize differences, and visual distinction of confusable items.[38,45,68] Similarly, reviews of human factors principles for medication safety alerts and decision support in clinical information systems by Phansalkar et al.[43] and Horsky et al.[51] establish the importance of factors such as placement, layout, proximity, alert visibility, prioritization, font, and use of colour for coding as well as consideration of the alarm logic, user mental models, and development of habitual behaviour by end users.

We also identified and reviewed several key documents and reports from the grey literature that describe usability principles for healthcare technology and eHealth. Reports from governmental and professional organizations such as the National Institute of Standards and Technology (NIST),[69,70] the Agency for Healthcare Research and Quality

(AHRQ),[71,72] and the Healthcare Information and Management Systems Society (HIMSS)[73] elaborate on general usability principles and describe their applicability and consequences of usability problems for electronic health records, electronic prescribing and CPOE, and other health information systems. The reports describe the application of usability principles, including broad principles (e.g. effectiveness, efficiency, learnability, satisfaction) and specific design factors (e.g. appropriate screen density, use of colour, consistency), for the design of the systems and provide guidance and models for usability testing. These efforts are intended to provide a pathway towards standardization of e-prescribing system and electronic health record usability, requirements for usability testing and documentation by vendors, and demonstrated system usability and safety as a requirement for certification.

Finally, we conducted a systematic search of the literature to identify usability or user interface evaluation studies that incorporated randomization in the study methodology. We searched using a combination of MeSH terms and title and abstract key words in Medline, Embase, and PsycInfo databases. To reduce the likelihood of missing studies that used randomization but may not have noted randomization in the study abstract we also searched the full texts of journals using a combination of keywords in the Full Text Journals @ Ovid and Journals @ ScholarsPortal databases available through McMaster University. We included studies that evaluated with clinician participants the usability and user interfaces of electronic prescribing systems, CPOE systems, electronic medical records, hospital information systems, or clinical decision support systems (CDSS), measuring any outcome and published in any year. One reviewer (WW) screened the title and abstracts, and subsequently the full texts of articles.

We excluded studies that did not utilize randomization in the study design, studies that evaluated usability for consumers and non-clinicians (e.g. for patient portals), studies that compared electronic systems versus paper, as well as conference abstracts and study protocols (see **Appendix 1**).

We identified 4[74-77] randomized controlled trials, and 12[78-89] experimental and crossover studies that used randomization in some component of the design.

Two RCTs assessed usability of decision support content in electronic medical records, with one investigating the impact of topic-specific 'infobuttons'[74] and the other active links to decision support on the home page.[76] One RCT assessed the impact of bolding and highlighting with colour patient information on patient selection errors in a CPOE system.[75] The last RCT assessed the impact of different methods of alerting, including pop-up alerts, in a CDSS on compliance with recommendations in the alerts.[77]

Of the 12 experimental and crossover study designs, 5 studies[78,81,85,88,89] compared user interfaces as a whole, 3 studies[79,82,84] evaluated medication order sets, and 4 studies[80,83,86,87] investigated specific user interface design features (e.g. graphical vs. table display, graphical vs. numerical display, graphical vs. textual display, alphabetical order vs. grouped medication list) (see **Appendix 1** for summary of included studies). Seven studies compared interfaces[78,81,85,88,89] or order sets[79,82] that were designed or re-designed based on usability principles, user input, or user testing to the standard, commercially-available interface or order set of the same system. All studies involved participants completing standardized tasks or clinical scenarios (e.g. completing an ordering task, making prescribing decisions, or answering questions about a patient case presented in the interface) using one type of interface versus the other. Sample sizes ranged from 7 to

148 participants, with 12 of the 16 studies having sample sizes of less than 50 participants. Randomization was most commonly used in the allocation of participants to complete the tasks or clinical scenarios starting with either the intervention or control interface, and in determining the order in which the tasks or clinical scenarios were presented.

1.7 Application of Design of Experiment (D.O.E.) Methodology to Evaluate User Interfaces

Our objective was to determine how specific user interface and usability factors impact the accuracy of prescribing. We sought to develop an evaluation method based on factorial experiment design that would allow for the testing of multiple individual user interface design factors.

To investigate the impact of specific user interface design features on the accuracy of prescribing, we aimed to develop a new methodology for the study of electronic prescribing system user interfaces based on design of experiment (D.O.E) methodology. While previous evaluations of clinical information system usability and user interface features have often relied on mostly subjective methods such as usability inspection, where an expert checks a system against specific usability guidelines, an objective, quantitative evaluation was planned. As opposed to relying on observations and subjective evaluation from users, this type of evaluation allows the quantification of the effect of specific user interface design features on prescribing accuracy, giving an objective and practical measure of the usability of an e-prescribing system.

D.O.E methods have broad application in many disciplines and are frequently used in engineering, where they play an important role in product design and process

improvement, and have also been applied in healthcare research. Experiments are performed by investigators to discover something about a particular process or system, they are a test in which purposeful changes are made to the input variables of a system so that researchers may observe and identify the reasons for changes that may be recorded in the output response. Experimental design methods also play a major role in design activities, where new products are developed and existing ones improved. Some applications of experimental design also include the evaluation and comparison of basic system design configurations.[90-92]

2.0 Project Objectives and Research Question

In evaluating the usability and user interface of an electronic prescribing system the goal is to determine whether a certain way of presenting information in the e-prescribing system interface will lead to more accurate interpretation and uptake of information and improve prescribing decision making.

The objectives for this project were:

1. To identify and describe the background about important user interface design factors that potentially impact usability, physicians' understanding and uptake of information, and accuracy of prescribing in e-prescribing systems that are described in the literature.
2. To conduct a study to evaluate the impact of e-prescribing user interface design factors on physicians' accuracy of prescribing when presented with prescribing scenarios in an e-prescribing system, with the following research questions:
    a) How does a specific subset of user interface design factors (density, highlighting, placement) impact physicians' prescribing accuracy?
    b) What are participants' preferences for specific user interface design factor configurations, and how do the factors impact preference?
    c) Are preferences for specific design factor configurations associated with improved prescribing accuracy when viewing user interfaces with the preferred configurations?

In designing and conducting the research project several methodological and analytic challenges were identified and addressed:

1. Identifying user interface design factors for evaluation: To identify important user interface design factors, a targeted review of the literature was required that would

incorporate both medical and the grey literature focusing on usability and user interface design principles applicable to e-prescribing systems.

2. Applying an efficient study design: Selecting an efficient experimental study design to evaluate the selected user interface design factors would allow for the testing of several important user interface design factors with the least amount of time required from study participants, while obtaining the necessary outcome data.
3. Selecting an appropriate study outcome: Determining how to best measure prescribing accuracy in the evaluation study was another methodological challenge. An outcome was required that was clinically meaningful, statistically feasible, and appropriate for the selected experimental study design. The outcome would have to be measured while controlling for any potential confounding and nuisance factors to isolate the effect on prescribing accuracy due to the user interface design factors.
4. Simulating an e-prescribing system and prescribing scenarios: A simulated e-prescribing system would have to be developed that allowed for manipulation of the user interface factors being evaluated and needed to be an accurate representation of a real-world system. The system would have to also be flexible for mock-up and evaluation of various configurations of the user interface design factors of interest. To reflect real-world prescribing, a sufficient number of appropriate prescribing scenarios, which would be presented on screenshots of the simulated e-prescribing system, needed to be developed.

3.0 Methods

3.1 Choice of Factorial Study Design

Adopting and modifying factorial design of experiment methodology, a factorial study design was developed to evaluate the impact of specific user interface design factors on the accuracy of prescribing by study participants. In a factorial experiment, if *k* factors are to be evaluated, each factor having two levels, the factorial design requires 2^k runs to present each possible configuration of the factors. For this particular study a 2^3 factorial design was selected to investigate the effect of 3 user interface design features, each set at one of two levels (a hypothesized suboptimal and a hypothesized optimal level), which required 8 unique e-prescribing user interface configurations to be presented to the participants.[90]

The study design allows for the investigation of the main effects of the factors on prescribing accuracy and any interactions that may exist between the 3 factors being studied (i.e. whether the effect of a factor varies in the presence or absence of another factor). An important feature of a factorial experiment is that they make the efficient use of experimental data.[90,92] The study design involves 8 observations for each participant, and all observations are used to calculate the 3 main effects as well as the interaction effects. Therefore, each study participant was able to view and respond to all prescribing scenarios and e-prescribing screen configurations with the application of a factorial study design.

With participants viewing and responding to all prescribing scenarios this factorial experiment allowed for a within-subjects design, where responses were compared within subjects. The study participant acts a control and any potentially

confounding subject variables, such as level of knowledge, do not account for any differences in prescribing accuracy between different user interface factor configurations.

Planning a factorial design experiment involves 3 basic design principles that must be taken into consideration: replication, blocking, and randomization.[90-92] Replication is the repetition of the experiment to collect more data and improve the reliability of the study. In this study design, each participant acts as a replicate of the experiment as each participant views all the prescribing scenarios and e-prescribing screen configurations. Blocking may be applied when an experiment is conducted at different times or settings and potential differences are suspected, and the data collected is grouped and analyzed by time or setting in blocks. Blocking was not utilized in this study design as no differences were suspected between study sites.

In addition to the basic experiment design, 6 additional screens were presented to the participants in addition to the 8 screens of the basic experimental design. With a similar look in the interfaces it was expected that a learning effect may exist and scenarios presented later in the run order would be answered better than earlier ones due to familiarity with screens. Participants seeing the same electronic prescribing system screens may learn in general where items are located and what to look for. Therefore, 4 additional screens were presented with repeated screen configurations of 4 previously presented screens but with a different prescribing scenario to determine whether the later scenarios would have a higher frequency of correct responses compared to the earlier runs; we referred to these as ‘factor duplicates’. Two of the 8 screens were presented after the run order as ‘exact duplicate’ screens to allow for measuring internal consistency.

The diagram in **Figure 1** provides an overview of the study design developed to evaluate the impact of specific user interface design features on the accuracy of prescribing. Eight prescribing scenarios displayed on screenshots of e-prescribing system user interfaces, with specific design factor configurations, were presented to the study participants. All possible configurations of the design factors, with each factor set at one of two levels, were evaluated. A prescribing accuracy score was obtained for each prescribing scenario and a total score is obtained for each user interface design.

3.2 Selection of Factors for Evaluation

The user interface design factors selected for evaluation in the factorial experiment were selected based on the targeted review of the literature described in Section 1.6. The number of factors selected for evaluation was based on feasibility of testing the factors in one study session and time constraints. The user interface design factors selected for evaluation were design factors and not content factors. All the same clinical information required to make a prescribing decision was available on the screens despite changing interfaces. In identifying all the factors that may have affected the outcome, several categories of factors are taken into consideration, which included the design factors, held-constant factors, and allowed-to-vary factors.[90]

The d*esign factors* are the factors of interest for evaluation in the study. The user interface design features selected for initial evaluation included the density of information on the screen, placement of key information on the screen, and the use of colour for highlighting, each set at one of two levels: low/high density, central/peripheral placement, and highlighting/no highlighting. *Held-constant factors* are factors that do not vary when conducting the study, which included the time given to each participant to

make prescribing decision. *Allowed-to-vary factors* are factors that change when conducting the study, which included participant level of training and prescribing knowledge, participant specialty, and the study session location, date and time of day. The allowed-to-vary factors were nuisance factors, which in this study design could have had an impact on prescribing accuracy. Participant level of training and specialty were measured to determine whether any relationship existed between these factors and differences in prescribing accuracy. Study session location, date and time of day were hypothesized to have a relatively little or no effect on prescribing accuracy.

3.3 Exact and Factor Duplicate Screens

To address 2 methodological concerns in the design of the study 2 types of duplicate e-prescribing screens were presented to participants after the initial run of 8. Four 'factor duplicate' screens, with repeated screen designs from the 8 main screens, but with different prescribing scenarios were presented. The same designs as the first, third, fifth, and seventh screen, respectively, were chosen for the factor *duplicate screens*, which provided repetition of screen designs throughout the run order. Two 'exact duplicate' screens, with the same screen design and prescribing scenario as the second and third screens were also presented to participants.

Despite the combination of variations in the screen design, participants viewing the same e-prescribing system screen may gain familiarity with the general look of the user interface. While design factors, including density, highlighting, and placement, may impact the accessibility of key information on the screen, participants viewing different screens of the same e-prescribing system may learn in general what to look for after viewing several screens. It was therefore anticipated that a learning effect might occur

and that prescribing scenarios presented later in the run order would be more likely to be answered correctly, regardless of screen design, due to familiarity with the user interface in general. However, it is also important to note that a learning effect could have the opposite consequence in that participants may begin to feel accustomed to the user interface and miss small changes, in particular on later screens. Presenting 4 factor duplicate screens with new prescribing scenarios near the end of the run order would allow for the measurement of the potential learning effect. A learning effect would result in higher prescribing accuracy scores in the 4 factor duplicate screens than the corresponding screens presented earlier.

The exact duplicate screens were presented to allow measurement of internal consistency in participants' prescribing decisions. Repeating the presentation of the second and third screens near the end of the run order could help determine whether participants were taking into consideration the same information when making their prescribing decision, and identify any issues in participants' responses such as attempts at guessing the correct answers. See **Table 1** for the screen design assignments for each study session.

3.4 Development of a Simulated E-Prescribing System and User Interface

One of the methodological challenges of this project was how the production environment involving a physician making prescribing decisions and selecting the appropriate medications using an electronic prescribing system could be translated to a research setting. A mock-up of an e-prescribing system was designed based on currently implemented electronic medical records with e-prescribing functionality, including HEC and HEO Systems, ABEL EHR, and OSCAR. This allowed for modification of specific

user interface design factors, as well as portability for presentation of the user interfaces and prescribing scenarios at various study sites. Choosing to design a simulated e-prescribing system allowed more control over the testing versus comparing commercially available e-prescribing system user interfaces, or attempting to modify commercially available system user interfaces. Currently available systems would be difficult to alter and would present a challenge in controlling any potential nuisance factors on the user interfaces, such as differences in clinical content.

Simulated user interfaces of a generic e-prescribing system were developed for each configuration of features using Microsoft Visio 2007 (Redmond, WA) (see **Appendix 2**). The simulated interface includes a header with patient information, a centrally placed prescribing frame, and central and peripheral frames that contain key clinical information.

3.5 Development of Prescribing Scenarios

To accompany the e-prescribing system user interface designs, 12 prescribing scenarios were developed by a clinical pharmacologist and internal medicine specialist (A.H.). The scenarios describe 8 specific types of *appropriateness of prescribing* problems, including:

- drug-drug interaction
- drug-allergy contraindication
- drug-lab value contraindication
- drug-disease contraindications
- drug-disease indication
- dose continuation
- drug duplication
- and drug duration

The prescribing scenarios were set up to have a predetermined correct or incorrect prescribing decision as study participants would need to decide whether to prescribe or not prescribe the drug presented in the prescribing scenario (see **Table 2**).

The goal in the development of the prescribing scenarios was to simulate high-risk prescribing scenarios where usability and content presentation in an e-prescribing system would be most important and could have more serious clinical implications (i.e. where prescribing errors would lead to harm). They represent common clinical scenarios encountered in internal medicine and focus on the older, high-risk patient and appropriateness of prescribing. All clinical information required for the prescribing decision was available on the e-prescribing screen, thereby separating the user interface design aspect from the clinical content aspect. The prescribing scenarios were developed with a level of complexity that would simulate real world prescribing. It was important to not include scenarios that all participants would answer correctly all the time regardless of user interface design, as this would not be informative and prevent gathering any useful data about potential differences in how information is processed when viewing the various screen designs.

The time to review and provide an answer for each scenario was set at 45 seconds. This time limit gave participants adequate time to answer each scenario. The given time would also fit within the study setting constraints enabling a session to be completed in 30 minutes mimicking a high-pressure prescribing scenario. Setting a time limit was necessary, as giving unlimited time may lead to a circumstance where most participants are able to answer the majority of prescribing scenarios correctly regardless of screen design. This would prevent gathering useful data on any potential differences in

prescribing accuracy due to screen design. The scenarios were pilot tested with a physician and a family medicine resident to determine whether there was adequate time to answer each scenario, whether difficulty of the scenarios was appropriate, and to identify any significant differences in difficulty of the prescribing scenarios.

3.6 Randomization

Randomization allows for any potential confounding factors to be distributed evenly in the study design so as to not have an impact on the outcome and minimize potential bias. In this study design the presentation order of the user interface screenshots and assignment of prescribing scenarios to user interface configurations were randomized between study sessions to wash out any confounding due to a potential learning effect with the presentation order, differences in difficulty for scenarios, and other unknown nuisance factors. Randomization schemes were created using a random number generator for each study session and prescribing scenarios were randomized to screen configuration 1 through 8, and then randomized to run order 1 through 8.

3.7 Selection of the Response Variable

Due to restricted time of the study sessions and the short time limit for each prescribing scenario a structured choice was necessary as a response variable. The primary outcome of interest was prescribing accuracy. Prescribing accuracy was measured as a binary outcome, with a correct prescribing decision scored a 1 and an incorrect prescribing decision scored a 0. Each prescribing scenario had a pre-determined correct prescribing decision (e.g., prescribe the drug vs. do not prescribe the drug), against which the participants' decisions were be scored. A binary outcome limited the

variability in responses and allowed for a clear response for each scenario. The drawback of a binary outcome was that it was not ideally representative of real-world prescribing. Most prescribing cases are not as clear-cut as a yes or no, and decisions often require follow-up. In addition to the prescribing decision, participants were also asked to give the reason for their prescribing decision in the form of a free-text comment.

3.8 Data Collection

A questionnaire was developed to serve as the data collection tool and response form. The questionnaire contained 4 sections to collect data on participant characteristics, participants' prescribing decisions, participants' user interface preferences, and study feedback. The first section of the questionnaire collected information on participant characteristics including their level of training and area of specialty. The second section of the questionnaire contained checkboxes for participants to record their prescribing decision for each prescribing case they viewed. The participating physician's decisions were scored as correct or incorrect in comparison to a pre-determined appropriate prescribing decision, giving a measure of prescribing accuracy for each prescribing scenario and user interface configuration. The final section of the questionnaire contained questions to gather participant feedback through 7-point Likert scales. After each study session a scoring sheet was used to mark the response questionnaires and aid in data entry (see **Appendix 3**).

3.9 Study Setting, Participants and Recruitment

The study was conducted during regularly scheduled Clinical Pharmacology and Therapeutics educational rounds, attended by house staff and medical students at

McMaster University Medical Centre (MUMC), St. Joseph's Healthcare Hamilton (SJH), Hamilton General Hospital (HGH), Stonechurch Family Health Centre (SFHC), and McMaster Family Practice (MFP). The participants mostly represented novice prescribers and users of electronic prescribing systems. Participants had some experience using e-prescribing systems at the different clinical sites of their training, mainly using the Oscar system at SFHC and MFP.

The first part of the rounds (approximately 30 minutes) consisted of the study, followed by a teaching session that reviewed the scenarios and presented concepts related to the study session, including medication safety, electronic prescribing systems, and high-risk prescribing scenarios. The prescribing scenarios were viewed on projection screen in a conference or meeting room using a PowerPoint presentation to control timing of slides. Two to three $10 Tim Horton's gift certificates were given out as prizes in a draw at each study session to thank for participation in the study.

3.10 Conducting the Study Sessions

An introduction to the study was given to the participants at the beginning of the rounds based on a pre-determined script. Study participants were instructed to review each prescribing scenario and provide their prescribing decision within the given time limit. They were also instructed to not go back and change their answers and to work individually and not share their answers. The study participants did not receive specific instructions prior to attending the educational rounds, they were only informed that the rounds would focus on the topic of medication safety and include an exercise on prescribing. Additionally, in introducing the prescribing exercise, the participants were not informed that the goal of the exercise was to evaluate user interfaces. Blinding the

study participants to the intent of the study was to ensure that participants did not have any preconceived notions or ideas about impact of user interface factors or to influence their responses based on preferences for specific screen design factors based on past experiences.

3.11 Data Quality and Analysis

A database was prepared using SPSS 17 software for data entry from the response questionnaires and for the data analysis. As several alterations were made between each study session, including prescribing scenario and run order randomization, data quality checks were performed prior to the analysis to ensure data from all study sessions were entered correctly into the database. Before each study session, the prescribing scenario presentation was checked for consistency with the randomization scheme and the questionnaire scoring sheet was checked for the correct coding. After each study session, the database setup and data entry was checked against a manual count of prescribing accuracy scores from the questionnaires to ensure correct data entry.

Descriptive statistics were used to summarize participant characteristics, prescribing accuracy scores, participant preferences, and feedback. We calculated means and standard deviation for continuous variables and frequencies for categorical variables. To analyze the primary outcome a Generalized Estimating Equation (GEE) was selected as the method of analysis. As the study design required each participant to work through all the prescribing cases, a measure of prescribing accuracy was obtained for each different screen design and each participant was given eight scores, providing for a repeated measures analysis with correlated data. A GEE is used to fit the parameters of a generalized linear model, allowing for the measurement of variance in prescribing

accuracy due to each screen design factor.[93] The advantage in choosing a GEE for analysis was that it would account for within-individual correlation, as repeated measures on the same participant are correlated, allow for the analysis of a binary outcome variable with non-normal distribution of data (i.e. correct or incorrect prescribing decision), and allow for the analysis of an unbalanced design where the number of observations per participant may not be the same due to missing data (e.g., a participant skipping a prescribing scenario). Using a binary logistic model with a logit link function, the output of the analysis includes the regression coefficients (beta; β), standard error for the coefficients, and the corresponding *p*-values, for each predictor variable. The β coefficient indicates the change in the log odds of the dependent variable (i.e. correct prescribing decision) for a unit change in the predictor variable, or for one value of the predictor variable (i.e. density, highlighting, placement set at +) versus the reference value (i.e. density, highlighting, placement set at -), after controlling for the confounding effects (i.e. holding constant) of the other predictor variables included in the model. For ease of interpretation, the β coefficient in this study design can be recalculated and expressed as the odds (e^{β} = odds) of a correct prescribing decision with the factor set at the hypothesized optimal (+) level over the odds of a correct prescribing decision with the factor set at the hypothesized suboptimal (-) level, and the odds ratio calculated for the predictor variable.[94]

All data was included in the analysis to minimize any potential selection bias due to exclusion of specific participants' data. The parameters for the GEE were as follows:

- Subject variable: participant
- Correlation matrix: exchangeable
- Type of model: binary logistic
- Response (dependent) variable: prescribing accuracy score

- Predictors: density, highlighting, placement
- Covariates: prescribing scenario, run order, study session

We first evaluated in the model the main effects for the predictors and all covariates. The covariates we adjusted for were identified in Section 3.2 as the nuisance factors in the study design and potential confounding variables. We then evaluated the main effects as well as all 2-way and 3-way interactions for the predictors, while adjusting for covariates that were found to be statistically significant predictors of prescribing accuracy.

In addition to the main analysis, a sensitivity analysis was planned to determine the effect that missing data had on the main outcome of the study. In the study design data could be missing due to participants having to leave in the middle of a study session and submitting responses for only the first few prescribing cases, arriving late for a study session, or when participants skipped a specific prescribing case and did not provide a response. The sensitivity analysis allowed for determining the impact of missing data, with two approaches that included excluding the data of participants who did not fully complete the study and marking all missing responses as incorrect.

3.12 Participant Screen Preferences Sub-Study

A secondary objective of the study was to determine participants' preferences for each of the screen design factors. Information on whether participants prefer the high (+) or low (-) level of each design factor (e.g., high vs low density of information on the screen) was collected. Preferences were measured using a paired comparison method. For the paired comparisons, the user interfaces in each pair varied only by the level of one design factor.

Preference for each design factor was measured twice, for a total of 6 paired comparisons (see **Table 3**). In the first paired comparison the factor of interest was varied between the two levels, while the other two factors were held constant at the high (+) level. In the second paired comparison, the other two factors were held constant at the low (-) level. Participants were given adequate time to view each screen in the paired comparison and record their preferred screen on the response questionnaire. The order of presentation of the six paired comparisons was randomized between study sessions. We analyzed the results for the paired comparison responses using the Chi-square Goodness of Fit test to determine the impact of the design, highlighting, and placement factors on preference (i.e. whether the proportion of observed responses differed from 50%).

Collecting data on participants' preferences for each design factor also allowed measurement of the association between screen design preference and prescribing accuracy. For each paired comparison we created a 2x2 contingency table to calculate prescribing accuracy on preferred vs. non-preferred screens and analyzed the results using McNemar's test to assess any effect of screen preference on prescribing accuracy. The McNemar test can be used for analysis of dichotomous dependent variables (e.g., repeated measure correct vs. incorrect prescribing decision from the paired comparisons). The aim was to determine whether participants had higher prescribing accuracy on screens where the design factor was set to their preference (e.g., whether a participant who preferred low density of information had higher accuracy on screens where density was set as low).

3.13 Ethical Considerations

A number of ethical issues were considered and addressed in planning the study and throughout the ethics review process. This study involved minimal risk to the participants. The participation of the house staff in the study during the educational rounds did not require any additional time or resources outside of their regular training activities. Their participation in the study was voluntary and it was assured that it would have no impact on their evaluation and was separate from their training. Issues around consent, privacy, collection of information, security were addressed when designing the study sessions and the data collection questionnaire. Consultation with members of the Research Ethics Board committee occurred to ensure compliance with ethical principles in these areas. Changes to the procedures that were made based on the feedback from the Research Ethics Boards included not collecting identifiable data as it was not critical to conduct the study and to its outcome and adding a consent statement at the top of the questionnaire for participants to review prior to the start of the study. The data collected would be stored in a secure, locked location to ensure data privacy. Ethics approval was granted from the McMaster Faculty of Health Sciences and St. Joseph's Healthcare Research Ethics Boards for all study sites.

4.0 Results

4.1 Description of study participants and study sessions

Five study sessions were conducted with a total of 68 participants. The study sessions held during Clinical Pharmacology and Therapeutics educational rounds at the five locations had varying numbers of participants: 13 participants at St. Joseph's Healthcare Hamilton, 13 participants at Hamilton General Hospital, 12 participants at McMaster University Medical Centre, 27 participants at Stonechurch Family Health Centre, and 3 participants at McMaster Family Practice. Two participants at the Stonechurch Family Health Centre session had previously participated in one of the earlier sessions and were excluded from analysis leaving a total of 66 participants.

The participants in the study sessions included residents and medical students. The level of training varied as most participants were first- or second-year residents (77%), 5% were third-year residents, and 15% were medical students. Fifty-two percent of the participants were specializing in family medicine and 25% were specializing in internal medicine (see **Table 4**).

4.2 Prescribing accuracy scores

The pooled prescribing accuracy for all scenarios presented at the study sessions across the 5 clinical sites ranged from 61.1% of all prescribing scenarios answered correctly to 78.6% of scenarios answered correctly. Of the 844 prescribing cases answered in total across the study sessions, 583 (69.0%) were answered correctly (see **Table 5**).

Individual mean participant prescribing accuracy scores across the study sessions ranged from 8.2 to 11.0 prescribing scenarios answered correctly out of 14 scenarios

presented, with an overall mean score of 8.8 (SD: 2.4, Range: 1 to 13) for all participants (see **Table 6**).

To observe any differences in prescribing accuracy between the different prescribing scenarios, we calculated the prescribing accuracy score for each scenario (see **Table 7**). The prescribing accuracy score for the scenarios ranged from 39.4% to 90.5%. Scenario 2 (Patient who has penicillin allergy is being prescribed Amoxicillin) and scenario 3 (Patient being prescribed Warfarin has supratherapeutic INR value of 3.7) were outliers, being answered correctly by 82% and 90% of the participants, respectively. Scenario 9 (Patient who has mild allergy to Statins, with small rise in AST and ALT being prescribed Atorvastatin) was similarly an outlier, being answered correctly by 39.4% of the participants. The prescribing scenario was adjusted for as a covariate in the main analysis (see Section 4.4).

To observe any potential learning effect and trend in prescribing accuracy of prescribing cases presented later versus those presented earlier in the study sessions, prescribing accuracy was calculated by run order in the presentation session (see **Table 8**). While no linear trend was observed (i.e. higher accuracy scores for cases presented later in the run order), prescribing accuracy scores varied throughout the run order. The run order was also adjusted for as a covariate in the main analysis (see Section 4.4). As the run order was adjusted for as a covariate, we did not include the factor duplicate screens in the analysis.

4.3 Reasons for prescribing decisions

The reasons for the participant's prescribing decisions for each prescribing scenario are summarized in **Table 9**, according to the prescribing decision made. For Scenario 1 the majority of participants noted in their reason for prescribing decision the potential drug-drug interaction. Those who answered the scenario correctly with a decision to prescribe sulfamethoxazole and trimethoprim noted the need to monitor the patient's INR value due to the potential interaction with warfarin. The majority of those who answered the question incorrectly also stated the potential drug-drug interaction as the reason to not prescribe. For Scenario 2, the majority of participants answered the question correctly and stated the patient allergy to penicillin as the reason to not prescribe. Scenario 3 was similarly answered correctly by the majority of participants, with the supratherapeutic INR value of 3.7 noted as the reason to not prescribe by all respondents. Scenario 4 was answered correctly by half the participants, with almost all participants noting the drug duplication between Tylenol #3 and acetaminophen as a reason not to prescribe. The few participants who provided a reason to prescribe Tylenol #3 noted an indication for it. Scenario 5 was answered correctly by two-thirds of the participants, with most noting the reason that the prescription was a renewal and that lab values were within normal range. The reasons for the incorrect decision to not prescribe the renewal of digoxin varied, with most not focusing on the drug-lab contraindication prescribing problem. Scenario 6 was answered correctly by half the participants, with those who answered the scenario incorrectly providing various reasons including no clear indication, inappropriate choice of drug, and a potentially confusing prescription script. Scenario 7 was answered correctly by two-thirds of the participants, with almost all participants noting that there was no indication for the drug in this scenario. Scenario 8

was answered correctly by the majority of participants, with the main reason noted for the decision to not prescribe hydromorphone being carbon dioxide retention. Scenario 9 was answered incorrectly by two-thirds of the participants, with the main reason for not prescribing the drug being the small rise in AST and ALT, while those who answered the scenario correctly noted the same reason for the decision and that the small rise was permissible. Scenario 10 was answered correctly by approximately two-thirds of the participants, with only a few of those who answered incorrectly noting the potential drug-duplication of clopidogrel and aspirin and several noting reasons that the duration of the prescription or the loading dosage was not appropriate. Scenario 11 was answered correctly by two-thirds of the participants, with most noting the drug-drug interaction and risk of lithium toxicity. Scenario 12 was similarly answered correctly by two-thirds of the participants, with most noting the high creatinine value as a contraindication for prescribing the drug.

4.4 Screen design and prescribing accuracy

4.4.1 Prescribing accuracy descriptive statistics

Table 10 shows the prescribing accuracy score for each screen configuration. The prescribing scenarios presented on the hypothesized worst screen design, with all factors set at the low level, had the lowest accuracy score as they were answered correctly by 51.7% of the participants, while the prescribing scenarios presented on the hypothesized best screen were answered correctly by 73% of the participants.

Table 11 shows the frequency of correct and incorrect prescribing decisions by the level of each design factor. Prescribing cases with highlighting present had a higher frequency of correct prescribing decisions (73.4% when set at + level vs. 64.5% when set

at - level), as did prescribing cases with low screen density (70.5% when set at + level vs. 66.5% when set at – level). For placement as a design factor, cases with decentralized placement had a slightly higher frequency of correct prescribing decisions (69.4% when set at – level vs. 67.6% when set at + level).

4.4.2 Model - Main Effects

In the test of model effects, prescribing scenario, run order, and study session were adjusted for as covariates in the model, being statistically significant predictors of prescribing accuracy. Of the 3 interface design factors evaluated, the presence of highlighting was found to be a statistically significant factor associated with correct prescribing decisions with *p*-value = 0.001, while low screen density and central placement of information were not found to be statistically significant predictors of correct prescribing decisions (*p*-values of 0.150 and 0.910, respectively) (see **Table 12**).

4.4.3 Model - Interactions

We then assessed the 3-way interaction and all 2-way interactions between the design factors. The 3-way interaction was not statistically significant (*p*-value = 0.903). All 2-way interactions were also not statistically significant, with *p*-value = 0.197 for Density x Highlighting interaction, *p*-value = 0.587 for Density x Placement interaction (see **Table 13**).

4.5 Description of missing data and sensitivity analysis

Of the 66 participants in the study, 15 had missing data. Four of these participants started the study session late and were missing several responses from the beginning of the run order, ranging from 3 to 10 missing responses. Of the remaining

participants with missing data, 2 participants were missing responses for two prescribing cases, while 9 were missing responses for a single prescribing case. Of the 15 participants with missing data, the most frequent screen design that did not have a response was the screen with all design factors at the suboptimal level (-,-,-), with 5 participants missing responses. Three of the 15 participants also did not provide a response to the screen with density set at the optimal level and the other factors set at the suboptimal level (+,-,-). No pattern was detected for missing responses with respect to the prescribing scenario, with various scenarios having missed responses.

Two approaches were taken in a sensitivity analysis to determine the impact of missing data. In the first approach, where all missing responses were marked as incorrect, highlighting remained a statistically significant predictor of prescribing accuracy in the main effects model (p-value < 0.001), with the other 2 design factors as well as 3-way and 2-way interactions remaining non-significant. In the second approach, where respondents with any missing data were excluded, highlighting also remained a statistically significant predictor of prescribing accuracy in the main effects model (p-value = 0.001), with the other 2 design factors as well as 3-way and 2-way interactions remaining non-significant.

4.6 Participant preferences

When asked about preference for each of the screen design factors using the 6 paired comparisons, the presence of highlighting was the only factor that the majority of participants preferred (80.3% of responses). No noteworthy difference was observed regarding the preference for screen density or placement of information, with 55.7% of

responses preferring low screen density and 49.6% of responses preferring central rather than dispersed placement of information (see **Table 14**).

There were no noteworthy differences in preferences when comparing responses between the two types of paired comparisons. Preferences were similar when the two factors not investigated were held constant at the high (+) level and at the low (-) level (i.e. comparison versus hypothesized optimal screen with all factors set at + level, or versus screen where all factors were not set at + level).

When assessing whether density, highlighting, and placement impacted preferences in the 6 paired comparisons, highlighting of information resulted in the largest differences in preference, with 87.9% (p-value < 0.001) preferring the highlighted screen when the other two factors were held constant at the high level, and 72.7% (p-value < 0.001) preferring the highlighted screen when the other two factors density and placement were set at the low and high level, respectively. The density and placement factors were found not statistically significant in each of the paired comparisons investigating those factors (*p-value* = 0.710 and 0.140 for density comparisons, and *p-value* = 0.806 and 0.710 for placement comparisons) (see **Table 15**). We also did not observe any noteworthy trends or differences in preferences between the five study sessions (see **Table 16**).

4.7 Screen preference and prescribing accuracy

The prescribing accuracy on preferred versus non-preferred screens for the 6 paired comparisons is provided in the 2x2 contingency tables in **Figure 2**. If hypothesized that participants would be more likely to make correct prescribing decisions on their preferred screens, we would expect a higher proportion of correct prescribing

decisions on the screen selected as preferred versus the screen selected as not preferred. Across the 6 paired comparisons, we observed that the higher proportion of correct prescribing decisions occurred for both preferred and non-preferred screens. When assessing the association between screen preference and prescribing accuracy, we did not identify a statistically significant effect in any of the six paired comparisons (*p*-values ranging from 0.078 to 0.700 across the 6 comparisons) (see **Table 17**).

4.8 Study feedback and participant comments

Several key themes were identified from participants' feedback. In general, participants agreed that they understood their role in the study. When asked to what extent the participants agreed on a 7-point scale (strongly disagree-strongly agree) that they were able to fully understand what they were asked to do in the study the mean score was 5.4. Participants also somewhat agreed that they did not have difficulty in completing the study (mean score 4.9). Finally, participants responded neutrally when they were asked if the time available for making the decisions was adequate (mean score 4.2) (see **Table 18**).

When asked an open-ended question about any changes that they would make to the study, 22 participants (35%) responded that they would make a change. When asked what they would change about the study, the key theme noted by the majority of respondents was that they wished to have more time to answer the prescribing scenarios, which would allow them the time to gather all the information they needed for decision making. This is in some contradiction to the results of our question about the adequacy of available time to complete the exercise. Participants also stated that a brief description with patient history, setting, and circumstances prior to presenting the e-prescribing

screen would have helped to better put the prescribing scenarios into the clinical context. Finally, several participants suggested that conducting the study in front of a computer screen, or at least having a printed version of the e-prescribing user interfaces in front of them, as opposed to projecting the images onto a screen at the front of the room would have made the user interfaces easier to view and made the setting more realistic (see **Table 19**).

When asked if any of the prescribing scenarios were unclear, 22 participants (35%) answered 'Yes'. While answering 'Yes', many participants could not recall the specific prescribing scenarios that were unclear, and only 5 participants identified specific scenarios that were problematic. Two participants identified scenario 6 (Patient taking antibiotic combination of ciprofloxacin and metronidazole for 2 weeks is asking for a refill), and one participant each identified scenario 5 (Patient is being prescribed digoxin renewal, 0.125 mg per day), scenario 8 (Patient with COPD is being prescribed hydromorphone, 1 mg QID), and scenario 9 (Patient who has allergy to statins is being prescribed Atorvastatin), as unclear (see **Table 19**).

5.0 Discussion

5.1 Findings

In this study we used a factorial experiment design to investigate the impact of specific user interface design factors on the accuracy of prescribing when viewing an e-prescribing system interface. The study design is a unique and novel method of user interface evaluation. It allows for an efficient approach to rapid evaluation of multiple user interface design factors in one study using simulated prescribing scenarios and assessing impact on prescribing accuracy.

5.1.1 User Interface Design and Prescribing Accuracy

We evaluated the effect of 3 specific user interface design factors on the prescribing accuracy of medical residents and students. Only the presence of highlighting of key clinical information on the screen was found as a significant predictor of prescribing accuracy. Density of information on the screen and the placement of the key clinical information were not statistically significant predictors. When evaluating interactions between the user interface design factors, we did not identify any statistically significant 3-way or 2-way interactions.

Possible explanations for the observed relationships may include increased attention due to the use of colour and bold font to highlight the key clinical information. As hypothesized, highlighting with colour may draw attention to the key information and enable the prescriber to focus on the key clinical information rapidly and spend the majority of the allotted time interpreting the information and making the correct prescribing decision, rather than spending more time searching for the necessary information on the screen. Highlighting the key clinical information may have allowed focusing on only the key clinical information required for the decision and to ignore the

other unnecessary information on the screen. Given that the prescribing scenario and all required information were presented on a single screen, the density of the screen may not have been found to be a significant predictor of accuracy as it may not have considerably impacted the accessibility of information on a single screen. Similarly, with all required information presented on a single screen, the placement of the information may not have been found to be a significant predictor of accuracy as the participants were able to still scan the entire screen quickly to find the key information and have sufficient time left to interpret the information and answer the prescribing scenario.

5.1.2 User Interface Design Preferences

We also assessed participants' preferences for each of the 3 user interface design factors. Only the highlighting design factor impacted participant preference, with majority of participants preferring the highlighted screen. We did not find differences in preference with respect to the screen density and placement of information factors. Similar to the explanation provided above, given that all information was presented on a single screen, the density of the screen and placement of information may not have been viewed as important to participants and did not impact their preferences. Furthermore, for the density factor, participants may have viewed more information on a screen as beneficial, even though the extra information was not required for making correct prescribing decisions.

When evaluating whether preferences for the user interface design factors were associated with prescribing accuracy, specifically whether participants would have higher prescribing accuracy on the screens that matched their preference, we did not find a statistically significant effect in any of the paired comparisons. A limitation to note is that

the setup of the 6 paired comparisons and the method chosen for the secondary analysis did not allow for adjustment for potentially confounding variables, including the prescribing scenario, as was performed in the main analysis. As certain screen designs were repeated between the 6 paired comparisons (e.g. + + + screen), with one prescribing decision provided for each screen design, this configuration did not permit evaluating screen preference as a variable in the generalized estimating equation, and we analyzed the 6 paired comparisons separately. For example, in one paired comparison the + + + screen may have been the preferred screen, with a correct prescribing decision response for that screen, while in a second paired comparison the + + + screen may have been the non-preferred screen, but also with the same correct prescribing decision for that screen.

5.2 Strengths of the Study and the Study Design

The factorial experiment study design allowed for an efficient evaluation of the impact of e-prescribing system user interface design features on the accuracy of prescribing. The 2^3 factorial design has a significant advantage over a one-factor-at-a time design as it allows for investigation of the effect of 3 user interface design factors in one study, as well as evaluation of any interactions between the design factors.[95]

In designing a study that is practical, efficient and feasible, we simulated the prescribing environment by developing static screenshots of an e-prescribing system user interface. We developed the configurable user interface screenshots using readily available computer software, without requirements for programming to design and configure the user interfaces. We also developed a set of realistic prescribing scenarios that represented various appropriateness of prescribing problems to accompany the user interfaces.

Another advantage of our study was that we selected an objective outcome measure of prescribing accuracy to evaluate the impact of the screen design factors. While some usability inspection and testing methods rely on subjective evaluation of user interfaces by end users, measuring prescribing accuracy allows for an objective evaluation of the impact of the user interface design. Usability issues that are identified using a subjective assessment, may not in fact impact task outcomes and, therefore, objective evaluations of user interfaces and system usability are also required.

Finally, the study methods used had low resource requirements and high feasibility. The factorial design allowed for the evaluation of 3 user interface design factors in a 30-minute study session, which allowed for the study to be conducted during regularly scheduled educational rounds. This in turn also allowed us to feasibly recruit participants for the study.

5.3 Limitations of the Study

There are several limitations to our study. While displaying to participants screenshots of an e-prescribing system screen permitted evaluation of user interface design factors for a single screen, a static screenshot of an electronic prescribing system interface does not fully represent a live system. In many cases, presenting all the required information to make a prescribing decision on a single screen may represent an ideal circumstance when compared to currently available e-prescribing systems. E-prescribing systems consist of multiple screens of information and require physicians to work though several steps and components to produce a prescription, which cannot be captured by a single screenshot of the e-prescribing system. While our approach allows for investigation of design factors of the user interface, and how the presentation of

information on the interface may influence prescribing accuracy, it does not allow for investigation of more complex human-computer interactions that occur during the process of e-prescribing, such as scrolling, switching between screens, and using selection functions and dropdown menus. The study design, therefore, fits into a specific role in the usability evaluation cycle of e-prescribing systems with applicability for the evaluation of the user interface design. It represents an advanced form of paper prototyping that provides a very useful component of usability testing in a feasible and cost-effective manner.

Our study design also exemplified the tradeoff for feasibility as we conducted the study in group sessions while projecting the user interface screenshots, and used a binary outcome measure of prescribing accuracy (i.e. correct vs. incorrect prescribing decision), versus a setting such as a usability simulation lab where participants could complete the prescribing scenarios individually in front of a computer. Conducting the study in a computer lab would allow for measurement of additional outcomes such as the time spent to make a prescribing decision. The use of a continuous outcome variable such as time to prescribing decision may be a more sensitive measurement to evaluate the impact of the screen design factors that could reveal the slight differences between the screen designs that would not be detected when using the binary outcome of correct versus incorrect prescribing decision. Although modifying three factors for the screen design configurations, the screens overall were not drastically different. For example, when evaluating the screen density and placement of information factors, the time to reach a prescribing decision may have been longer when viewing the hypothesized suboptimal screens as compared to the hypothesized optimal screens, but still sufficient to make a

correct prescribing decision. Conducting the study in a computer lab would also allow for the randomization of prescribing scenarios to the screen configurations and of the run order at the individual-level rather than at the block-level. It is important to note though that recruiting participants to a study session in a computer lab during a specified time would be more difficult.

The study requires the use of various prescribing scenarios to accompany the 8 possible user interface designs, and it is challenging to develop prescribing scenarios that are similar in difficulty. As a result, we observed differences in prescribing accuracy across the prescribing scenarios. The difference in difficulty of the prescribing scenarios is a nuisance factor in the study design as it may be associated with prescribing accuracy, and can be adjusted for in the analysis. As noted above, while our study methods applied randomization of prescribing scenarios between study sessions (at the block-level), performing the study in a computer lab with individual-level randomization could allow more ideal distribution of prescribing scenarios across the screen configurations and the run order.

Finally, we investigated prescribing decisions of mostly novice users of e-prescribing systems, who do not represent the full range of e-prescribing users, and may differ from expert users who may have more extensive experience viewing various e-prescribing system interfaces. A representative study population is needed to adequately evaluate a system, and while this study involved mainly novice e-prescribing users, giving the perspective of the ‘new user’, a variety of expert and novice users is ideal and future evaluations should be conducted with participants representative of the end users of the systems in a clinical environment (i.e. occasional, routine, expert users).

5.4 What the Study Adds

In our review of the literature, we identified few rigorous usability and user interface evaluation studies that incorporated randomization in the study design. Five of the 16 studies (31%) identified compared user interfaces as a whole, 3 studies (19%) evaluated the usability of medication order sets as a whole, 8 studies (50%) investigated the impact of individual user interface design or usability features, and no study investigated the impact of multiple individual user interface design features. The majority of usability evaluations of e-prescribing and CPOE systems, as reported in systematic reviews,[38,45] consist of the application of traditional usability testing methods such as heuristic evaluation.

Usability problems continue to be one of the primary reasons for dissatisfaction and poor levels of adoption of e-prescribing, CPOE systems, and other health information technology.[39,96] Evidence-based design factors and usability principles, as well as standardization for system usability, are needed to inform and improve the design of e-prescribing systems.[69,70,72] The factorial randomized experiment design we used in our study allows for the evaluation of the impact of individual user interface design factors, as well as known usability principles and heuristics. It provides an efficient, low-cost approach to investigate multiple factors in one study, with large sample sizes, and measurement of an objective outcome that can be applied for both formative and summative evaluation of user interfaces. Our investigation of design factors, including highlighting, density, and placement of information, emphasizes user interface design as a critical component to the success of e-prescribing systems, which require full-scale evaluation prior to implementation.

5.5 Relevance of Study for Current Implementation Efforts

The study methodology we developed is intended to provide an approach for efficient evaluation of e-prescribing system interfaces. The study methodology provides a tool that can be used to obtain important information about the design of user interfaces that does not require much time or resources. Given the variations between different e-prescribing and CPOE systems, both home-grown and commercially available, as well as differences in clinical settings between and within hospitals and outpatient clinics, the study methodology provides a viable approach to rapidly deploy and conduct usability tests with current end users in a specific setting, for a specific system.

The study demonstrated that user interface design factors, such as highlighting of information, may have an impact on the usability of an e-prescribing system and consequently the accuracy of prescribing. E-prescribing and CPOE systems have a significant impact on clinical workflow, and any usability issues will adversely affect that workflow as well as user satisfaction.[97,98] Identification and evaluation of factors that relate to usability and quality of decision support will ultimately enhance the design and appropriate use of e-prescribing systems and the likelihood of their successful adoption and benefit on patient safety.

5.6 Suggestions for Future Application of Study Design

As noted in the study limitations, conducting the study sessions during education rounds enabled for the recruitment of a large number of study participants, who otherwise would be difficult to recruit due to busy schedules. However, the setting does not provide an ideal controlled environment for the presentation and evaluation of e-prescribing user

interfaces. A computer lab with individual screens for each participant and timed slides for the e-prescribing screens being evaluated would allow for a more controlled experiment that is still removed from the production environment, but would pose additional recruitment challenges. Incorporating into the study design additional real-world simulation, such as the patient encounter, could further enhance the applicability of the study and might more accurately reflect the highly complex clinical conditions in which a system will actually be used.[99,100]

A supplementary qualitative study component with think-aloud methods or a follow-up interview or focus group of participants would be helpful to determine exactly how participants viewed the screen and worked through the scenarios to help determine how the factors played into and influenced their understanding and uptake of information from the screen, and determine what impact they may have had on their behavior (i.e. prescription selection). This mixed methods approach would allow an in-depth understanding and to more precisely answer the question of how the user interface design features impact the prescribing decision making.[101]

In addition to evaluating the impact of user interface design factors on the accuracy of prescribing, the study design can be applied throughout the system development lifecycle, including formative and summative evaluations. The study design may also be applied to evaluate content or information factors, rather than user interface design factors, with a comparison of e-prescribing system screens that provide various levels of content, such as information intended for clinical decision support. This would allow for the study of 'what information is presented' versus 'how information is presented', or a combination of both research questions. With minor modifications to the

user interface screenshots, the study design will also allow for the investigation of other potentially important user interface design features.

5.7 Implications for Future Research, Policy and Practice

The findings from this study provide information about the impact of specific interface design factors that may improve the accuracy of prescribing and relate to the usability of e-prescribing systems. This information is intended to inform future research on the design and implementation of e-prescribing systems. The research is important as it will help determine which design factors make electronic prescribing systems more user-friendly, less prone to error, and aid in making correct prescribing decisions.

The work conducted in this research project contributes to the pool of evidence on usability in e-prescribing systems. While some progress has been made and e-prescribing systems have the potential to aid clinicians, there remain gaps in knowledge regarding the net benefits of the systems and the readiness for adoption of e-prescribing, particularly in outpatient settings.[19] Usability evaluations of e-prescribing systems have been isolated and often specific to particular systems or healthcare settings, providing few objective and generalizable outcomes. Future applications of the study design developed for this project could allow for evaluation of other key e-prescribing system user interface design features with a variety of users, with the goal of identifying and contributing to evidence-based usability standards.

Further research on the impact of availability of specific clinical content such as lab results and decision support during prescribing will contribute additional evidence on the key features of an e-prescribing system user interface that aid in prescribing. On a broader scale, the potential value of e-prescribing systems as a whole requires

investigation, to determine the benefit and appropriate use. Rigorous evaluations are needed to determine the success or failure of e-prescribing systems and set the ground for definitive trials to evaluate their effectiveness on patient safety and patient-important outcomes.

6.0 Conclusion

The goal of this project was to develop a methodology to investigate and gain a clearer understanding of e-prescribing system user interface design factors that potentially impact usability and acceptability of e-prescribing systems. We applied a factorial design methodology to investigate the impact of user interface design factors including screen density, highlighting, and placement of information, on the accuracy of physicians' prescribing. In our study, we identified the presence of highlighting of key clinical information in the e-prescribing system user interface to be a predictor of prescribing accuracy, as well as a design factor that impacted participants' screen preferences. Applying the findings from our study and utilizing the study design to investigate the impact of additional user interface design factors will contribute to improve the evidence about e-prescribing system usability. As e-health and specifically e-prescribing implementation efforts proceed and the number of users increases, information on the factors that impact usability and accuracy with use of these systems is widely applicable. Further study will be necessary to identify and evaluate all potentially important user interface design factors that may eventually be incorporated into design standards for e-prescribing systems intended to enhance appropriate use.

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Figures

Figure 1: Basic Study Design Diagram

Run (Prescribing Case)	Screen Design Factor Assignment			Participant Prescribing Score			
	A	B	C	Group 1 Participant 1-n_1	Group 2 Participant (n_1+1)-n_2	Group N Participant (n_2+1)-n_N	Total
1	-	-	-	0 or 1	0 or 1	0 or 1	0-N
2	+	-	-	"	"	"	"
3	-	+	-	"	"	"	"
4	+	+	-	"	"	"	"
5	-	-	+	"	"	"	"
6	+	-	+	"	"	"	"
7	-	+	+	"	"	"	"
8	+	+	+	"	"	"	"

Figure 2: 2x2 Contingency Tables for Screen Preference vs. Prescribing Accuracy

Paired comparison 1: – + + Screen vs. + + + Screen (Density comparison)

Decision on Non-Preferred Screen	Decision on Preferred Screen: Incorrect	Decision on Preferred Screen: Correct	Total:
Incorrect	4	13	17
Correct	17	27	44
Total:	21	40	

Paired comparison 4: – – + Screen vs. + – + Screen (Density comparison)

Decision on Non-Preferred Screen	Decision on Preferred Screen: Incorrect	Decision on Preferred Screen: Correct	Total:
Incorrect	3	13	16
Correct	20	24	44
Total:	23	37	

Paired comparison 2: + – + Screen vs. + + + Screen (Highlighting comparison)

Decision on Non-Preferred Screen	Decision on Preferred Screen: Incorrect	Decision on Preferred Screen: Correct	Total:
Incorrect	6	17	23
Correct	9	28	37
Total:	15	45	

Paired comparison 5: – – + Screen vs. – + + Screen (Highlighting comparison)

Decision on Non-Preferred Screen	Decision on Preferred Screen: Incorrect	Decision on Preferred Screen: Correct	Total:
Incorrect	6	12	18
Correct	15	29	44
Total:	21	41	

Paired comparison 3: + + – Screen vs. + + + Screen (Placement comparison)

Decision on Non-Preferred Screen	Decision on Preferred Screen: Incorrect	Decision on Preferred Screen: Correct	Total:
Incorrect	5	8	13
Correct	12	36	48
Total:	17	44	

Paired comparison 6: + – – Screen vs. + – + Screen (Placement comparison)

Decision on Non-Preferred Screen	Decision on Preferred Screen: Incorrect	Decision on Preferred Screen: Correct	Total:
Incorrect	7	15	22
Correct	6	27	33
Total:	13	42	

Tables

Table 1: Screen Design Assignment

Study Session	Scenario	Run Order	Screen Design		
			D	H	P
1: SJHH	1	7	-	+	+
	2	5	+	-	-
	3	6	+	+	+
	4	2	-	+	-
	5	8	+	+	-
	6	1	+	-	+
	7	4	-	-	-
	8	3	-	-	+
	Factor Duplicates				
	9	12	+	+	-
	10	13	+	+	+
	11	10	+	-	+
	12	14	-	-	+
	Exact Duplicates				
	2	9	+	-	-
	3	11	+	+	+
2: HGH	1	5	+	-	+
	2	8	-	-	+
	3	3	-	-	-
	4	4	+	-	-
	5	7	+	+	+
	6	6	-	+	+
	7	1	-	+	-
	8	2	+	+	-
	Factor Duplicates				
	9	9	+	-	+
	10	12	-	-	-
	11	13	+	+	+
	12	10	-	+	-
	Exact Duplicates				
	8	11	+	+	-
	3	14	-	-	-
3: MUMC	1	3	-	+	-
	2	6	+	+	+
	3	8	+	-	-
	4	1	-	-	-

	5	4	-	-	+
	6	5	+	+	-
	7	2	-	+	+
	8	7	+	-	+
	Factor Duplicates				
	9	12	-	-	-
	10	9	-	+	-
	11	13	+	+	-
	12	10	+	-	+
	Exact Duplicates				
	7	11	-	+	+
	1	14	-	+	-
4: SFHC	1	2	+	+	+
	2	3	-	-	+
	3	7	-	+	+
	4	9	+	-	+
	5	1	+	-	-
	6	6	-	-	-
	7	5	+	+	-
	8	4	-	+	-
	Factor Duplicates				
	9	13	+	-	-
	10	12	-	-	+
	11	10	+	+	-
	12	9	-	+	+
	Exact Duplicates				
	1	11	+	+	+
	2	14	-	-	+
5: MFP	1	4	+	+	-
	2	8	-	-	-
	3	1	-	+	-
	4	3	-	+	+
	5	2	+	-	-
	6	6	-	-	+
	7	5	+	-	+
	8	7	+	+	+
	Factor Duplicates				
	9	13	-	+	-
	10	9	-	+	+
	11	12	+	-	+
	12	10	+	+	+
	Exact Duplicates				
	5	11	+	-	-
	4	14	-	+	+

Table 2: Prescribing Scenarios with Predetermined Correct Prescribing Decision

Prescribing Scenario	Patient Information	Type of Prescribing Problem	Information Required for Prescribing Decision	Central Idea of Prescribing Scenario	Correct Prescribing Decision
1. 75/F Patient taking Warfarin (Coumadin) long-term, 2 mg 1 OD, is being prescribed Sulfamethoxazole & Trimethoprim (Nu-Cotrimox), 400/80 mg 1 BID for 7 days, Qty: 14.	**Dx Current**: UTI **Dx Past**: atrial fibrillation, osteoporosis, osteoarthritis **Labs**: INR 1.9, eGFR 55 ml/min, creatinine 111 µmol/L **Meds**: Coumadin 2 mg, Metoprolol 50 mg, Naproxen 500 mg, Calcium 1200 mg	Drug-Drug Interaction	- Current Medications - Lab Values - DI Warning	Sulfamethoxazole & Trimethoprim interacts with Warfarin to raise INR. Need to see that INR value is mildly subtherapeutic and risk of bleeding is low despite interaction being flagged.	Prescribe
2. 29/F Patient who has penicillin allergy is being prescribed Amoxicillin (Amoxil), 500 mg 1 q8h for 7 days, Qty: 21.	**Dx Current**: sinusitis **Dx Past**: endometriosis, mild asthma **Meds**: Folic acid 0.8 mg **Specific Allergy**: urticaria	Drug-Allergy	- Patient Allergies - History of Specific Allergy Outcome	Prescribing drug that patient has serious allergy to. Need to see specific allergy finding.	Do Not Prescribe
3. 85/M Patient taking Warfarin (Coumadin) long-term, 2 mg 1 OD, requires refill/dose continuation for 30 days, Qty: 30.	**Dx Past**: pulmonary embolism, atrial fibrillation, thyroid tumour **Labs**: INR 3.0 (2 weeks ago), INR 3.7 (current), creatinine 130 µmol/L **Meds**: Coumadin 2mg, Metoprolol 50 mg, Vitamin D 1000 IU, Levothyroxine 0.125 mg	Dose Continuation	- Lab Values - Current Medications and Dose	INR value has increased over last 2 weeks. Need to see current INR and adjust (lower) Warfarin dose.	Do Not Prescribe
4. 35/M Patient is being prescribed Acetaminophen-Codeine (Tylenol #3),	**Dx**: Crohn's disease, recent bowel resection **Labs**: serum albumin 28 g/L **Meds**: Acetaminophen 650	Drug Duplication	- Current Medications	Tylenol #3 and Acetaminophen are drug duplicates. Need to see Acetaminophen in	Do Not Prescribe

300/30 mg 2 every 4-6 hours, as needed, Qty: 90. Patient is already taking Acetaminophen, 650 mg QID.	mg, Mesalamine 400 mg, Budesonide 9mg,			current medications list to avoid duplicate prescription.	
5. 82/M Patient is receiving prescription renewal for Digoxin (Lanoxin), 0.125 mg 1 OD for 30 days, Qty: 30.	**Dx**: recent rapid atrial fibrillation admission (30 days ago), CHF, hypertension **Labs**: creatinine 130 µmol/L, potassium 3.8 mmol/L, serum digoxin 0.8 nmol/L **Meds**: Digoxin 0.125 mg, Metoprolol 75 mg, Hydrochlorthiazide 25 mg	Drug-Lab	- Current Medications - Lab Values	If potassium level is low there is a risk of Digoxin toxicity. Need to see that potassium level is in normal range.	Prescribe
6. 67/M Patient taking antibiotic combination of Ciprofloxacin (Cipro) and Metronidazole (Flagyl) 500 mg & 1 g 1 each q12h for 14 days, Qty: 28 each, is receiving a refill.	**Dx Current**: diabetic foot **Dx Past**: hypertension, diabetes **Labs**: HbA1c 0.08, creatinine 130 µmol/L, HDL 1.3 mmol/L, LDL 4.1 mmol/L **Clinical Notes**: Temperature normal. Breathing normal. Foot looks improved. **Meds**: Ciprofloxacin 500 mg, Metronidazole 1 g, Metoprolol 50 mg, Rosuvastatin 10 mg	Drug-Duration	- Current Medications - Diagnosis	Patient has long duration of antibiotics. Need to see diagnosis of diabetic foot and realize that it is fine to prescribe refill.	Prescribe
7. 89/F Patient is being prescribed Risperidone (Risperdal), 0.5 mg each night for 7 days, for insomnia. Patient	**Dx Current**: insomnia **Dx Past:** hypertension, osteoarthritis, breast tumour, depression **Labs**: HDL 1.8 mmol/L,	Drug-Indication	- Diagnosis	Risperidone is an atypical antipsychotic, not a short-term medication for insomnia. Not indicated as patient	Do Not Prescribe

lives alone and has normal mental status.	LDL 3.1 mmol/L, creatinine 130 μmol/L **Clinical Notes:** Mental status: Normal. **Meds**: Metoprolol 50 mg, Naproxen 500 mg			has normal mental status.	
8. 56/M Patient is being prescribed Hydromorphone (Dilaudid), 1 mg 1 QID, as needed, Qty: 60. Patient has COPD and severe CO_2 retention.	**Dx Current**: pain **Dx Past:** COPD, pneumonia, asthma, depression **Labs**: serum CO_2 59 mmol/L, creatinine 130 μmol/L **Clinical Notes**: Breathing difficulties. Severe CO_2 retention. **Meds**: Salbutamol 100 mcg (2 pump PRN), Advair 250 mcg (1 puff BID)	Drug-Disease Contraindication	- Diagnosis - Lab Values	Narcotics depress breathing and are not appropriate for this patient. Need to see diagnosis of COPD, severe CO_2 retention, and high serum CO_2 levels.	Do Not Prescribe
9. 64/M Patient who has allergy to Statins, small rise in AST and ALT, is being prescribed Atorvastatin (Lipitor), 10 mg 1 OD for 60 days, Qty: 60.	**Dx**: hypercholesterolemia, MI (1 year ago), hypertension **Labs**: creatinine 120 μmol/L, potassium 3.8 mmol/L, LDL 3.2 mmol/L **Meds**: ASA 80 mg, Ramipril 10 mg **Specific Allergy**: AST, ALT small rise	Drug-Allergy (Factor Duplicate Scenario)	- Patient Allergies - History of Specific Allergy Outcome	Prescribing drug that patient experiences a mild allergy with. Need to see specific allergy finding, and that it is fine to prescribe with small rise in AST and ALT, given benefit of the drug.	Prescribe
10. 60/M Patient is being prescribed Clopidogrel (Plavix), 300 mg loading dose, followed by 75 mg 1 OD for 90 days with 3 repeats, for acute	**Dx Current**: hospitalization for acute coronary syndrome **Dx Past:** hypertension, osteoarthritis **Labs**: troponin 0.09, HbA1c 0.06, creatinine 130 μmol/L, **Meds**: ASA 80 mg, Ramipril	Drug Duplication (Factor Duplicate Scenario)	- Current Medications - Diagnosis - DI Warning	Prescribing antiplatelet to patient. Need to see Aspirin (an over-the-counter drug) in current medications list and that it is flagged as an interaction, but it is fine	Prescribe

coronary syndrome. Patient is already taking Aspirin (ASA), 80 mg 1 OD.	10 mg, Vitamin D 1000 IU, Metoprolol 50 mg			to prescribe Clopidogrel as it is not true drug duplication.	
11. 68/M Patient currently taking lithium, with an outdated last blood level of 0.9 µmol/L, is being prescribed a refill for Hydrochlorthiazide (Apo-Hydro), 25 mg 1 OD for 60 days, after taking it for 1 month.	**Dx Past**: hypertension, bipolar disorder, depression **Labs**: HbA1c 0.08, creatinine 120 µmol/L, lithium 0.9 µmol/L (1 year ago) **Clinical Notes**: Patient presents with ataxia. Complains of dizziness, nausea, and weakness. **Meds**: Lithium 300 mg, Hydrochlorthiazide 25 mg	Drug-Drug Interaction (Factor Duplicate Scenario)	- Current Medications - Lab Values - DI Warning	Diuretics (hydrochlorthiazide) increase lithium blood level, increasing risk of lithium toxicity. Drug interaction if flagged. Need to see that last lithium blood level is outdated and clinical notes are indicating symptoms of lithium toxicity.	Do Not Prescribe
12. 45/M Patient currently taking Insulin 30/70, 30 units BID, is being prescribed Metformin (Glucophage), 500 mg 1 BID for 30 days, Qty: 60. Patient has reduced renal function.	**Dx Past**: diabetes, pneumonia, asthma **Labs**: HbA1c 0.085, creatinine 250 µmol/L **Meds**: Insulin 30/70 30 U	Drug-Lab (Factor Duplicate Scenario)	- Current Medications - Lab Values	Reduced renal function is associated with increased risk of hypoglycemia in patients with diabetes. Reduced renal function also increases risk of lactic acidosis. Need to see high creatinine level.	Do Not Prescribe

Table 3: Paired Comparison Assignment

Study Session	Pair	Factor Investigated	Screen Configurations Compared		Presentation Order
			Left Screen	Right Screen	
1: SJHH	1	Density	+ + +	- + +	4
	2	Highlighting	+ - +	+ + +	1
	3	Placement	+ + +	+ + -	6
	4	Density	- - +	+ - +	5
	5	Highlighting	- + +	- - +	3
	6	Placement	+ - +	+ - -	2
2: HGH	1	Density	+ + +	- + +	2
	2	Highlighting	+ - +	+ + +	5
	3	Placement	+ + +	+ + -	3
	4	Density	- - +	+ - +	4
	5	Highlighting	- + +	- - +	1
	6	Placement	+ - +	+ - -	6
3: MUMC	1	Density	+ + +	- + +	5
	2	Highlighting	+ - +	+ + +	1
	3	Placement	+ + -	+ + +	4
	4	Density	- - +	+ - +	2
	5	Highlighting	- + +	- - +	6
	6	Placement	+ - +	+ - -	3
4: SFHC	1	Density	+ + +	- + +	1
	2	Highlighting	+ - +	+ + +	2
	3	Placement	+ + +	+ + -	5
	4	Density	- - +	+ - +	3
	5	Highlighting	- + +	- - +	6
	6	Placement	+ - -	+ - +	4
5: MFP	1	Density	+ + +	- + +	3
	2	Highlighting	+ - +	+ + +	4

	3	Placement	+ + +	+ + -	2
	4	Density	+ - +	- - +	6
	5	Highlighting	- + +	- - +	5
	6	Placement	+ - -	+ - +	1

Table 4: Participant Characteristics

Participant Characteristics	**Study Population** *(n=66)*
Level of Training	*n (%)*
Clerkship	10 (15.4)
First-Year Resident	32 (49.2)
Second-Year Resident	19 (29.2)
Third-Year Resident	3 (4.6)
Other	1 (1.5)
Total:	65
Specialty	*n (%)*
Medical Student	10 (15.6)
Emergency Medicine	1 (1.6)
Family Medicine	33 (51.6)
Internal Medicine	16 (25.0)
Obstetrics and Gynaecology	1 (1.6)
Orthopaedics	1 (1.6)
Pharmacy Resident	1 (1.6)
Radiation Oncology	1 (1.6)
Total:	64

Table 5: Score for Scenario with Screen Design and Run Order by Group

Study Session	**Scenario**	**Run Order**	**Screen Design**			**Correct** *n (%)*	**Incorrect** *n (%)*	**Total** *n*
			D	H	P			
1: SJHH N = 13	1	7	-	+	+	5 (41.7)	7 (58.3)	12
	2	5	+	-	-	9 (75.0)	3 (25.0)	12
	3	6	+	+	+	12 (100.0)	0 (0.0)	12
	4	2	-	+	-	8 (66.7)	4 (33.3)	12
	5	8	+	+	-	9 (75.0)	3 (25.0)	12
	6	1	+	-	+	7 (58.3)	5 (41.7)	12
	7	4	-	-	-	6 (60.0)	4 (40.0)	10
	8	3	-	-	+	8 (66.7)	4 (33.3)	12
	FD: 9	12	+	+	-	4 (30.8)	9 (69.2)	13
	FD: 10	13	+	+	+	7 (53.8)	6 (46.2)	13

	FD: 11	10	+	-	+	7 (58.3)	5 (41.7)	12
	FD: 12	14	-	-	+	10 (76.9)	3 (23.1)	13
	ED: 2	9	+	-	-	9 (75.0)	3 (25.0)	12
	ED: 3	11	+	+	+	13 (100.0)	0 (0.0)	13
	Group 1 Total:					**114 (67.1)**	**56 (32.9)**	**170**
2: HGH N = 13	1	5	+	-	+	5 (41.7)	7 (58.3)	12
	2	8	-	-	+	12 (92.3)	1 (7.7)	13
	3	3	-	-	-	10 (83.3)	2 (16.7)	12
	4	4	+	-	-	3 (27.3)	8 (72.7)	11
	5	7	+	+	+	5 (38.5)	8 (61.5)	13
	6	6	-	+	+	6 (50.0)	6 (50.0)	12
	7	1	-	+	-	7 (58.3)	5 (41.7)	12
	8	2	+	+	-	8 (66.7)	4 (33.3)	12
	FD: 9	9	+	-	+	3 (23.1)	10 (76.9)	13
	FD: 10	12	-	-	-	9 (69.2)	4 (30.8)	13
	FD: 11	13	+	+	+	9 (69.2)	4 (30.8)	13
	FD: 12	10	-	+	-	8 (61.5)	5 (38.5)	13
	ED: 8	11	+	+	-	11 (84.6)	2 (15.4)	13
	ED: 3	14	-	-	-	11 (84.6)	2 (15.4)	13
	Group 2 Total:					**107 (61.1)**	**68 (38.9)**	**175**
3: MUMC N = 12	1	3	-	+	-	10 (83.3)	2 (16.7)	12
	2	6	+	+	+	11 (91.7)	1 (8.3)	12
	3	8	+	-	-	12 (100.0)	0 (0.0)	12
	4	1	-	-	-	2 (16.7)	10 (83.3)	12
	5	4	-	-	+	8 (66.7)	4 (33.3)	12
	6	5	+	+	-	8 (66.7)	4 (33.3)	12
	7	2	-	+	+	6 (50.0)	6 (50.0)	12
	8	7	+	-	+	8 (72.7)	3 (27.3)	11
	9 (FD)	12	-	-	-	10 (83.3)	2 (16.7)	12
	10 (FD)	9	-	+	-	6 (50.0)	6 (50.0)	12
	11 (FD)	13	+	+	-	6 (50.0)	6 (50.0)	12
	12 (FD)	10	+	-	+	8 (66.7)	4 (33.3)	12
	ED #1: 7	11	-	+	+	4 (33.3)	8 (66.7)	12
	ED #2: 1	14	-	+	-	6 (54.5)	5 (45.5)	11
	Group 3 Total:					**105 (63.3)**	**61 (36.7)**	**166**
4: SFHC N = 25	1	2	+	+	+	17 (73.9)	6 (26.1)	23
	2	3	-	-	+	17 (73.9)	6 (26.1)	23
	3	7	-	+	+	20 (83.3)	4 (16.7)	24
	4	9	+	-	+	14 (60.9)	9 (39.1)	23
	5	1	+	-	-	16 (80.0)	4 (20.0)	20
	6	6	-	-	-	10 (43.5)	13 (56.5)	23
	7	5	+	+	-	19 (82.6)	4 (17.4)	23
	8	4	-	+	-	20 (87.0)	3 (13.0)	23
	9 (FD)	13	+	-	-	9 (36.0)	16 (64.0)	25

	10 (FD)	12	-	-	+	13 (54.2)	11 (45.8)	24
	11 (FD)	10	+	+	-	20 (80.0)	5 (20.0)	25
	12 (FD)	9	-	+	+	13 (52.0)	12 (48.0)	25
	ED #1: 1	11	+	+	+	15 (60.0)	10 (40.0)	25
	ED #2: 2	14	-	-	+	21 (84.0)	4 (16.0)	25
	Group 4 Total:					**224 (67.7)**	**107 (32.3)**	**331**
5: MFP N = 3	1	4	+	+	-	3 (100.0)	0 (0.0)	3
	2	8	-	-	-	3 (100.0)	0 (0.0)	3
	3	1	-	+	-	3 (100.0)	0 (0.0)	3
	4	3	-	+	+	3 (100.0)	0 (0.0)	3
	5	2	+	-	-	2 (66.7)	1 (33.3)	3
	6	6	-	-	+	1 (33.3)	2 (66.7)	3
	7	5	+	-	+	3 (100.0)	0 (0.0)	3
	8	7	+	+	+	1 (33.3)	2 (66.7)	3
	9 (FD)	13	-	+	-	0 (0.0)	3 (100.0)	3
	10 (FD)	9	-	+	+	3 (100.0)	0 (0.0)	3
	11 (FD)	12	+	-	+	3 (100.0)	0 (0.0)	3
	12 (FD)	10	+	+	+	3 (100.0)	0 (0.0)	3
	ED #1: 5	11	+	-	-	2 (66.7)	1 (33.3)	3
	ED #2: 4	14	-	+	+	3 (100.0)	0 (0.0)	3
	Group 5 Total:					**33 (78.6)**	**9 (21.4)**	**42**
	Grand Total:					**583 (69.0)**	**261 (31.0)**	**844**

Table 6: Participant Mean Total Score by Group

Study Session	**Participant Total Score** *mean [SD] (Min-Max)*	**Group Size** *n*
1: SJHH	8.8 [3.1] (1-13)	13
2: HGH	8.2 [1.4] (6-11)	13
3: MUMC	8.8 [2.2] (5-13)	12
4: SFHC	9.0 [2.5] (2-12)	25
5: MFP	11.0 [1.7] (9-12)	3
All Groups:	8.8 [2.4] (1-13)	66

Table 7: Scenario Score for All Groups

Scenario	**Correct** *n (%)*	**Incorrect** *n (%)*	**Total** *N*
1	40 (64.5)	22 (35.5)	62
2	52 (82.5)	11 (17.5)	63
3	57 (90.5)	6 (9.5)	63
4	30 (49.2)	31 (50.8)	61
5	40 (66.7)	20 (33.3)	60

6	32 (51.6)	30 (48.4)	62
7	41 (68.3)	19 (31.7)	60
8	45 (73.8)	16 (26.2)	61
9	26 (39.4)	40 (60.6)	66
10	38 (58.5)	27 (41.5)	65
11	45 (69.2)	20 (30.8)	65
12	42 (63.6)	24 (36.4)	66
Grand Total:	488 (64.7)	266 (35.3)	754

- Scenarios 9-12 are factor duplicates for all sessions

Table 8: Case Score for All Groups

Case (Run Order)	**Correct** *n (%)*	**Incorrect** *n (%)*	**Total** *n*
1	35 (59.3)	24 (40.7)	59
2	41 (66.1)	21 (33.9)	62
3	48 (77.4)	14 (22.6)	62
4	40 (67.8)	19 (32.2)	59
5	44 (71.0)	18 (29.0)	62
6	40 (64.5)	22 (35.5)	62
7	39 (61.9)	24 (38.1)	63
8	50 (79.4)	13 (20.6)	63
9	34 (52.3)	31 (47.7)	65
10	46 (70.8)	19 (29.2)	65
11	45 (68.2)	21 (31.8)	66
12	39 (60.0)	26 (40.0)	65
13	31 (47.0)	35 (53.0)	66
14	51 (78.5)	14 (21.5)	65
Grand Total:	583 (66.0)	301 (34.0)	884

- Cases 9 and 11 were exact duplicates for Session 1, and cases 11 and 14 were exact duplicates for Sessions 2-5

Table 9: Reasons for Prescribing Decisions

N Total = 66
* N for some prescribing scenarios <66 due to missing responses

Prescribing Scenario	Participant Prescribing Decision (*n*)	Reason for Prescribing Decision (direct quote)
1. 75/F Patient taking Warfarin (Coumadin) long-term, 2 mg 1 OD, is being prescribed Sulfamethoxazole & Trimethoprim (Nu-Cotrimox), 400/80 mg 1 BID for 7 days, Qty: 14. **Dx Current**: UTI **Dx Past**: atrial fibrillation, osteoporosis, osteoarthritis **Labs**: INR 1.9, eGFR 55 ml/min, creatinine 111 µmol/L **Meds**: Coumadin 2 mg, Metoprolol 50 mg, Naproxen 500 mg, Calcium 1200 mg ***Correct Prescribing Decision***: Prescribe	**Prescribe** Group 1= 5 Group 2= 5 Group 3= 10 Group 4= 17 Group 5= 3 Total= 40	Group 1: • Pt on coumadin – monitor Group 3: • has UTI, septra is indicated • allergies - symptomatic? Group 4: • need to monitor coumadin - INR • UTI • Bacterial UTI, no apparent contraindications • with repeat INR in 5d • Dx bacterial UTI • no allergies Group 5: • But would need to monitor INR
	Do Not Prescribe Group 1= 7 Group 2= 7 Group 3= 2 Group 4= 6 Group 5= 0 Total = 22	Group 1: • on coumadin • on coumadin • Sulpha & Coumadin interaction • Interaction with coumadin • on coumadin - interaction • Need to check INR more frequently • interaction with warfarin Group 2: • On coumadin • Drug interaction (increase in INR) • Cipro instead • insufficient Hx • Coumadin • On coumadin • Interact with warfarin Group 3: • dose duration not appropriate • increase in INR Group 4: • Previous UTI, interact? • penicillin allergy • coumadin interference • Not first line treatment for UTI in elderly

		• would want to know sensitivity first • length of time
2. 29/F Patient who has penicillin allergy is being prescribed Amoxicillin (Amoxil), 500 mg 1 q8h for 7 days, Qty: 21. **Dx Current**: sinusitis **Dx Past**: endometriosis, mild asthma **Meds**: Folic acid 0.8 mg **Specific Allergy**: urticaria ***Correct Prescribing Decision*:** Do Not Prescribe	**Prescribe** Group 1= 3 Group 2= 1 Group 3= 1 Group 4= 6 Group 5= 0 Total = 11	<u>Group 4:</u> • Pt's name not written • sinusitis
	Do Not Prescribe Group 1= 9 Group 2= 12 Group 3= 11 Group 4= 17 Group 5= 3 Total = 52	<u>Group 1</u>: • Penicillin allergy • Pen allergy • Allergy to penicillin • Pen allergy • Allergy to Penicillin • Allergic to PCN • Pt allergic to penicillin - urticaria • Allergy • Allergy <u>Group 2</u>: • Allergy • Allergic to penicillin • Allergy to PCN • q8h dosing • PEN allergic • No evidence of bacterial infection • Insufficient Hx • Urticaria w. Pen • Penicillin allergy • Pen allergy • Allergic to penicillin <u>Group 3</u>: • Allergy to penicillin • Possible allergic reaction • Allergy • why need this? • Penicillin allergy • allergy • All. to penicillin • pt allergy – penicillins - clarify first • allergies (pen/eryth) • pt. has all. to penicillin • cross reactivity

<table>
<tr><td></td><td></td><td>Group 4:
Allergy data
penicillin allergy
Allergy to penicillin
Penicillin allergy
allergy penicillin
allergy to penicillin
Allergy
Allergic to penicillin
Allergy
Allergic
Allergy to penicillin
Allergic to penicillin
penicillin allergy
allergy
Allergy
Group 5:
Allergy listed
Penicillin allergy
Allergy</td></tr>
<tr><td rowspan="2">3. 85/M Patient taking Warfarin (Coumadin) long-term, 2 mg 1 OD, requires refill/dose continuation for 30 days, Qty: 30.

Dx Past: pulmonary embolism, atrial fibrillation, thyroid tumour
Labs: INR 3.0 (2 weeks ago), INR 3.7 (current), creatinine 130 μmol/L
Meds: Coumadin 2mg, Metoprolol 50 mg, Vitamin D 1000 IU, Levothyroxine 0.125 mg

Correct Prescribing Decision: Do Not Prescribe</td><td>Prescribe

Group 1= 0
Group 2= 2
Group 3= 0
Group 4= 4
Group 5= 0

Total = 6</td><td></td></tr>
<tr><td>Do Not Prescribe

Group 1= 12
Group 2= 10
Group 3= 12
Group 4= 20
Group 5= 3

Total = 57</td><td>Group 1:
INR 3.7
INR 3.7
INR 3.7
INR 3.7
INR supratherapeutic
INR too high
Need INR checked
INR increased
INR = 3.7. Pt may require lower dose.
INR 3.7; as per INR
INR greater than therapeutic level
Needs instruction for INR monitoring
Group 2:
Warfarin - INR high, greater than 3
Not clear about INR check
High INR; F/U? (Should hold + re-evaluate 1</td></tr>
</table>

		week with FP) • High INR • Supratherapeutic INR • INR 3.7 • Outside therapeutic range (INR too high, 3.7) • INR 3.7 • INR is 3.7 (high target) <u>Group 3</u>: • INR is 3.7 • INR 3.7 last. Want to recheck first. • INR • decrease dose as INR increased • changing dose? • INR is above therapeutic level, need it in 2-3 range • Giving reg dose - but INR increased to 3.7 • INR 3 before, don't know previous coumadin dose • monitor INR, don't prescribe for 30 days • not enough info • INR = 3.7 • adjust dose for therapeutic range <u>Group 4:</u> • lessen strength, INR, add on Rx hold or as per INR protocol • INR 3.7 - hold coumadin as INR not therapeutic • INR too high • INR high at 3.7 • unsure of fall risk • Recent INR 3.7 • INR supratherapeutic at last visit • INR? • INR 3.7 last visit • high INR • INR is high • INR 3.7 • Last INR high on warfarin 2mg - "as per INR" needed. • 85 yr old with 1 month supply and no mention of INR check frequency • would comment on the Rx, as directed by MD. May need to adjust dose in future, INR high. • INR 3.7 on Mar. 3, 2010 • INR 3.7

<table>
<tr><td></td><td></td><td>• INR high
Group 5:
• Most recent INR 3.7, high
• INR 3.7 - need to decrease dose
• High INR beyond therapeutic range</td></tr>
<tr><td rowspan="2">4. 35/M Patient is being prescribed Acetaminophen-Codeine (Tylenol #3), 300/30 mg 2 every 4-6 hours, as needed, Qty: 90. Patient is already taking Acetaminophen, 650 mg QID.

Dx: Crohn’s disease, recent bowel resection
Labs: serum albumin 28 g/L
Meds: Acetaminophen 650 mg, Mesalamine 400 mg, Budesonide 9mg,

Correct Prescribing Decision: Do Not Prescribe</td><td>Prescribe

Group 1= 4
Group 2= 8
Group 3= 10
Group 4= 9
Group 5= 0

Total = 31</td><td>Group 2:
• Tylenol regular 650x4; #3 4-6 hrs
Group 3:
• pain = missed work
• has GI history, no known liver issue
• no reason not to
Group 4:
• indication, chron's</td></tr>
<tr><td>Do Not Prescribe

Group 1= 8
Group 2= 3
Group 3= 2
Group 4= 14
Group 5= 3

Total = 30</td><td>Group 1:
• Decrease # tabs
• Already taking 650 mg tylenol QID
• Already on acetaminophen
• Already taking Tylenol 650 QID
• Too many pills Rx. Give fewer pills + investigate pain.
• Also on Tylenol, decrease no. tabs
• Put (Ninety) after qty. so pt. cannot alter qty.
Group 2:
• Already on 650 mg QID Tylenol
• check pain mgmt
Group 3:
• Chron's flare up? other tx
• b/c acet. already on
Group 4:
• Crohn's Dx
• Dr's name not written
• also taking acetaminophen 650 QID, too much in combo
• too many given - indication for such pain meds?
• indication, chron's
• Already taking 650 mg Tyl QID - need to d/c
• Already on Acetaminophen
• Tylenol, too much
• Pt is on Reg T. + too many pills for 1 prescription
• no clear etiology for pain
• Pt on another acetaminophen dose and directions need to be specific</td></tr>
</table>

		• Already on Tylenol 650 mg QID • Already on Tylenol 650 mg QID <u>Group 5:</u> • Pt on Acetaminophen 650mg po QID, too much Tylenol • Already on acetaminophen 650mg - would be too much • Already on acetaminophen 650 QID
5. 82/M Patient is receiving prescription renewal for Digoxin (Lanoxin), 0.125 mg 1 OD for 30 days, Qty: 30. **Dx**: recent rapid atrial fibrillation admission (30 days ago), CHF, hypertension **Labs**: creatinine 130 µmol/L, potassium 3.8 mmol/L, serum digoxin 0.8 nmol/L **Meds**: Digoxin 0.125 mg, Metoprolol 75 mg, Hydrochlorthiazide 25 mg ***Correct Prescribing Decision*:** Prescribe	**Prescribe** Group 1= 9 Group 2= 5 Group 3= 8 Group 4= 16 Group 5= 2 Total = 40	<u>Group 1</u>: • if previously done • cautious with high Cr, low K <u>Group 2</u>: • CHF • level o.k. with chronic renal insufficiency • Dg level ok, creat 130 <u>Group 3</u>: • Repeat • A.fib • similar dose, therapeutic range 0.8 <u>Group 4:</u> • Afib., pt. is getting serum levels checked • Rapid A-fib • has had before, renewal • Dig level ok, previously prescribed • no contraindication, long term Rx <u>Group 5:</u> • Pt has Afib., likely for Rate Control
	Do Not Prescribe Group 1= 3 Group 2= 8 Group 3= 4 Group 4= 4 Group 5= 1 Total = 20	<u>Group 1</u>: • High Cr • high creatinine • needs digoxin/K+ levels monitored <u>Group 2</u>: • Metop/Dig • Chronic kidney disease (possible increase in Dig level); follow up with FP • Need more info on CHF • Don't know pt's New York Heart Association classification • Hx A.Fib, CHF • Dose too high (loading) - should be 0.0625 daily <u>Group 3</u>: • CHF, AFib, worsen CHF • Due to narrow therapeutic index, try something else for Afib • metoprolol not maximized - only daily dose

		not BID • no clear indication Group 4: • Needs to check Dig level + adjust • would want digoxin normal value with the test value • Age, renal function, on beta blocker Group 5: • baseline Cr
6. 67/M Patient taking antibiotic combination of Ciprofloxacin (Cipro) and Metronidazole (Flagyl) 500 mg & 1 g 1 each q12h for 14 days, Qty: 28 each, is receiving a refill. **Dx Current**: diabetic foot **Dx Past**: hypertension, diabetes **Labs**: HbA1c 0.08, creatinine 130 µmol/L, HDL 1.3 mmol/L, LDL 4.1 mmol/L **Clinical Notes**: Temperature normal. Breathing normal. Foot looks improved. **Meds**: Ciprofloxacin 500 mg, Metronidazole 1 g, Metoprolol 50 mg, Rosuvastatin 10 mg ***Correct Prescribing Decision*:** Prescribe	**Prescribe** Group 1= 7 Group 2= 6 Group 3= 8 Group 4= 10 Group 5= 1 Total = 32	Group 2: • But need LU code for Cipro Group 3: • Increased risk of infection with diabetes Group 4: • Diabetic foot - needs Rx • good Rx for diabetic ulcer
	Do Not Prescribe Group 1= 5 Group 2= 6 Group 3= 4 Group 4= 13 Group 5= 2 Total = 30	Group 1: • 2 drugs should be prescribed separately • High creatinine • the prescription can make Pt confused • Drug doses • Separate Rx for each drug Group 2: • Not sure of indication • query past history • ? Infection - need to confirm • CRI • Unknown indication? • Need to renally dose cipro Group 3: • Already presc.? • where is the indication for it? • not appropriate flagyl dose - not adj. cipro for renal impairment • why flagyl? Group 4: • each drug separate line • what is the indication? • Have to prescribe separately • indication? • no swab done, do not renew Abx if not effective & no swab • need separate prescription

<table>
<tr><td></td><td></td><td>• no clear indication
• very confusing instructions/directions for pt.
• would separate both, confusing
• no reason for refill
• I would separate the 2 drugs into separate Rx
<u>Group 5:</u>
• What is the indication for 2 antibiotics
• Consider change Abx, already received course</td></tr>
<tr><td rowspan="2">7. 89/F Patient is being prescribed Risperidone (Risperdal), 0.5 mg each night for 7 days, for insomnia. Patient lives alone and has normal mental status.

Dx Current: insomnia
Dx Past: hypertension, osteoarthritis, breast tumour, depression
Labs: HDL 1.8 mmol/L, LDL 3.1 mmol/L, creatinine 130 µmol/L
Clinical Notes: Mental status: Normal.
Meds: Metoprolol 50 mg, Naproxen 500 mg

Correct Prescribing Decision: Do Not Prescribe</td><td>Prescribe

Group 1= 4
Group 2= 5
Group 3= 6
Group 4= 4
Group 5= 0

Total = 19</td><td><u>Group 3</u>:
• appears stable, will not abuse</td></tr>
<tr><td>Do Not Prescribe

Group 1= 6
Group 2= 7
Group 3= 6
Group 4= 19
Group 5= 3

Total = 41</td><td><u>Group 1</u>:
• Indication unknown
• ? Insomnia
• Risperidone is not for use for insomnia. Not a short term medication (7 days!)
• What indication?
• No indication
<u>Group 2</u>:
• Atypicals increase risk in elderly
• ? indication
• insufficient Hx
• I don't know that drug, sorry
<u>Group 3</u>:
• Short term use, already feels tired
• Re-evaluate - depression & need for that med
• not indicated for insomnia
• not necessary
• increased mortality in elderly
<u>Group 4</u>:
• increased risk of all-cause mortality in elderly pts on atypical neuroleptics
• No Dx to support
• no indication? normal mental status
• indication?
• Not to use in elderly
• indication?
• Not indicated as first line for insomnia</td></tr>
</table>

<table>
<tr><td></td><td></td><td>• indication?
• indication unclear
• no indication
• need to assess the pt
• no clear indication
• Antipsychotic for just 7 days?
• need to know reason for med; lives alone
• alcohol use + children in house
• old age
<u>Group 5:</u>
• No indication
• No indication
• Inappropriate use</td></tr>
<tr><td rowspan="2">8. 56/M Patient is being prescribed Hydromorphone (Dilaudid), 1 mg 1 QID, as needed, Qty: 60. Patient has COPD and severe CO_2 retention.

Dx Current: pain
Dx Past: COPD, pneumonia, asthma, depression
Labs: serum CO_2 59 mmol/L, creatinine 130 μmol/L
Clinical Notes: Breathing difficulties. Severe CO_2 retention.
Meds: Salbutamol 100 mcg (2 pump PRN), Advair 250 mcg (1 puff BID)

Correct Prescribing Decision: Do Not Prescribe</td><td>Prescribe

Group 1= 4
Group 2= 4
Group 3= 3
Group 4= 3
Group 5= 2

Total = 16</td><td><u>Group 2</u>:
• But watch for breathing difficulties
<u>Group 3</u>:
• but w/ resp concern
<u>Group 4</u>:
• ok to use with dyspnea</td></tr>
<tr><td>Do Not Prescribe

Group 1= 8
Group 2= 8
Group 3= 8
Group 4= 20
Group 5= 1

Total = 45</td><td><u>Group 1</u>:
• Decrease # tabs
• COPD
• COPD - Resp. depression
• COPD; CO2 retention
• decrease tabs; CO2 retention
• Resp. depression
• Put (Sixty) after qty. so pt. cannot alter qty.
<u>Group 2</u>:
• Dilaudid - CO2 high - too much in the prescript
• Resp. difficulties
• Hx breathing difficulties; severe CO2 retention
• Large doses, Hx CO2 retention, change in level of consciousness with Dilaudid
• Breathing difficulties
• CO2 retention
• CO2 retention
• Breathing difficulties
<u>Group 3</u>:
• Try lower pain med first
• resp. depression with high CO2 already</td></tr>
</table>

		• Long acting might be more appropriate. Very potent analgesic. • breathing troubles, do we want to further Resp. depression • severe COPD • pt has resp. problems - clarify first? • clinical notes - try other analgesic first • not enough information <u>Group 4:</u> • COPD/asthma • breathing difficulties - risk of resp. depression/CO2 retention • no other pain meds documented as initial choice • no obvious indication for medication • no name • Not 1st line for pain, i.e. no indication • CO2 retention • no other pain meds prev. tried • prefer less potent Rx for narcotic – alcohol use • CO2 retention, resp. depression • CO2 retention, prescription not written correctly • Breathing difficulties and severe COPD, PRN not good • Time on script not given and not proper directions for patient • narcotic, need to specify quantity and dispensing instructions • Alcohol use, CO2 retention • severe CO2 retention <u>Group 5:</u> • What other medications have been tried prior
9. 64/M Patient who has allergy to Statins, small rise in AST and ALT, is being prescribed Atorvastatin (Lipitor), 10 mg 1 OD for 60 days, Qty: 60. **Dx**: hypercholesterolemia, MI (1 year ago), hypertension **Labs**: creatinine 120 μmol/L, potassium 3.8 mmol/L, LDL 3.2 mmol/L	**Prescribe** Group 1= 4 Group 2= 3 Group 3= 10 Group 4= 9 Group 5= 0 Total = 26	<u>Group 1</u>: • ok with small AST/ALT rise, watch LFTs <u>Group 2</u>: • MI in past • Only small rise AST/ALT • Only small rise in AST/ALT <u>Group 3</u>: • Needs just follow LFT • High LDL • has Hx of hypercholesterolemia and MI, may be preventative • Dx registry + allergies (small rise) adjust

Meds: ASA 80 mg, Ramipril 10 mg **Specific Allergy**: AST, ALT small rise ***Correct Prescribing Decision*:** Prescribe		dosage approp. • dyslipidemia despite small rise ALT AST <u>Group 4:</u> • Only small rise AST+ALT • would need BW for LFTs, CK info - myopathy • indicated, no clear contraindications • High cholesterol
	Do Not Prescribe Group 1= 9 Group 2= 10 Group 3= 2 Group 4= 16 Group 5= 3 Total = 40	<u>Group 1</u>: • previous drug reaction • higher dose needed; follow up AST/ALT • increase dose of lipitor; MI, high cholesterol • increase in transaminasil with statin • Insufficient dose • AST, ALT increase • small rise AST,ALT • Allergy • Allergy - small rise AST/ALT <u>Group 2</u>: • Lipitor - rise in AST/ALT in past • Says liver enzymes raise • Statin allergy • Documented statin allergy, needs clarification • Hx statin adverse reaction with rise in AST etc. • Allergy to statin • Statin allergy • Allergy to statin • Known reaction to statin • LDL normal, and causes rise in LFT in this pt <u>Group 3</u>: • Allergy to statin - small rise in AST/ALT • AST/ALT rise last statin <u>Group 4:</u> • Allergy to statin? Investigate • increase in AST/ALT although "small rise" may not be an issue • Allergy to statins • Pt's name & Dr's not written • Allergic to statin • statin allergy • Cr 120. Previous statin transaminitis. Need more info. • allergies

		• Allergy, AST, ALT rise • All. to statins • Statin allergy • Allergy • Pt has some CV risk factors and dose might be low - no liver enzymes seen • Evidence of previous rise in AST/ALT on statin • Should be QID; allergic <u>Group 5:</u> • Rise in AST/ALT listed in allergies; labs to repeat • Check baseline ALT + CK - previous rise in ALT • Current AST/ALT adverse rxn; if ok, need higher dose
10. 60/M Patient is being prescribed Clopidogrel (Plavix), 300 mg loading dose, followed by 75 mg 1 OD for 90 days with 3 repeats, for acute coronary syndrome. Patient is already taking Aspirin (ASA), 80 mg 1 OD. **Dx Current**: hospitalization for acute coronary syndrome **Dx Past:** hypertension, osteoarthritis **Labs**: troponin 0.09, HbA1c 0.06, creatinine 130 µmol/L, **Meds**: ASA 80 mg, Ramipril 10 mg, Vitamin D 1000 IU, Metoprolol 50 mg ***Correct Prescribing Decision*:** Prescribe	**Prescribe** Group 1= 7 Group 2= 9 Group 3= 6 Group 4= 13 Group 5= 3 Total = 38	<u>Group 1</u>: • but pt should stop naproxen • Stop naproxen! <u>Group 2</u>: • Trops elevated • ACS - although no ECG/Hx <u>Group 3</u>: • ACS hospitalization • ASA, Plavix • vascular Hx - on ASA but plavix might be synergistic <u>Group 4:</u> • ACS *Note: Naproxen was included in current medications list in scenario presented to Group 1, and removed from the scenario for all groups thereafter.*
	Do Not Prescribe Group 1= 6 Group 2= 4 Group 3= 6 Group 4= 11 Group 5= 0 Total = 27	<u>Group 1</u>: • 1 yr prescription needed • 1 year needed • troponin 0.09; ACS hospitalization • D/C naproxen 1st • On naproxen, potential G.I. bleed • Duration too short <u>Group 2</u>: • No loading as outpatient. Only 75 OD. • Creat 130 • On ASA already. ACS confirmed? <u>Group 3</u>: • Increased risk of bleeding - using ASA already

		• not appropriate loading clopidogrel if already on • indication not clear • values + ASA - not nec. • only 75, already loaded! <u>Group 4:</u> • cannot see all allergies • write separately • Plavix is given only 3 months. Do not agree with repeats. • I would not Rx for 1 yr. without follow-up • already on ASA • ASA • 3x repeats, monitoring needed • script flagged because pt already on a blood thinner • would specify if loading dose is x1 or for how many days *Note: Naproxen was included in current medications list in scenario presented to Group 1, and removed from the scenario for all groups thereafter.*
11. 68/M Patient currently taking lithium, with an outdated last blood level of 0.9 µmol/L, is being prescribed a refill for Hydrochlorthiazide (Apo-Hydro), 25 mg 1 OD for 60 days, after taking it for 1 month. **Dx Past**: hypertension, bipolar disorder, depression **Labs**: HbA1c 0.08, creatinine 120 µmol/L, lithium 0.9 µmol/L (1 year ago) **Clinical Notes**: Patient presents with ataxia. Complains of dizziness, nausea, and weakness. **Meds**: Lithium 300 mg, Hydrochlorthiazide 25 mg ***Correct Prescribing Decision*:** Do Not Prescribe	**Prescribe** Group 1= 5 Group 2= 4 Group 3= 6 Group 4= 5 Group 5= 0 Total = 20	<u>Group 2</u>: • Chronic kidney disease or acute? If acute renal failure, no Rx. <u>Group 3</u>: • no Hx of diabetes, has hypertension • appropriate for htn
	Do Not Prescribe Group 1= 7 Group 2= 9 Group 3= 6 Group 4= 20 Group 5= 3 Total = 45	<u>Group 1</u>: • lithium (flagged) • HCTZ; lithium toxicity • hypotension (dizziness/weakness) • high Cr = 120 • Pt on lithium; inc levels • Lithium toxicity secondary to renal failure • weakness = check K+ <u>Group 2</u>: • HCTZ + Lithium - with symptoms of lith tox • assess for postural hypotension • Start with ACE • Dizziness could be low Na+ • Li + HCTZ – hypercalcemia • Interaction with Li

		• Interacts with lithium • Renal failure • Interaction btw. Lith./HCTZ - causing hypercalcemia Group 3: • Already on HCTZ 25 mg • Can affect dizzy; HCTZ • Another BP med. Not related to clinical notes • Li narrow therapeutic window - Li toxic • address clinical complaints • worsening kidney - leading to Ch. Li tox. Group 4: • Pt on lithium • on lithium, x diuretics • lithium + diuretic - dehydration risk • lithium toxicity in notes • May affect lithium levels • What's BP? • Dr's name & pt's name not on the script • dizzy? hypotension • lithium toxicity - possibly diuretic induced • Possible lithium toxicity with electrolyte imbalance • most recent electrolytes? most recent bp? • Concern re: Li toxicity with presenting complaints - HCTZ may worsen • needs ACE • ? orthostatic hypotension • HbA1c = 0.08, can further worsen • risk of fall • on Li, high Cr • Poor kidney function - investigate further • Script flagged as pt on lithium • History of dizziness and ataxia Group 5: • Dig level 0.8? Normal range. Lithium Tox. • Check electrolytes + pt. dizzy • Needs electrolytes, Li level
12. 45/M Patient currently taking Insulin 30/70, 30 units BID, is being prescribed Metformin (Glucophage), 500 mg 1 BID for 30 days, Qty: 60. Patient has reduced renal function.	**Prescribe** Group 1= 3 Group 2= 5 Group 3= 4 Group 4= 12 Group 5= 0	Group 2: • T2DM (on insulin first?) Group 3: • on insulin • High A1c, high creatinine - need something to add to insulin Group 4: • quantity should be 120 though

Dx Past: diabetes, pneumonia, asthma **Labs**: HbA1c 0.085, creatinine 250 µmol/L **Meds**: Insulin 30/70 30 U ***Correct Prescribing Decision*:** Do Not Prescribe	Total = 24	• DMII, high HgA1C, no obvious contraindication
	Do Not Prescribe Group 1= 10 Group 2= 8 Group 3= 8 Group 4= 13 Group 5= 3 Total = 42	Group 1: • High Cr • would increase insulin • Cr 250 • high Cr • high Cr • Creatinine 250 (high); Poor kidney function • high Cr • Creat 250 • Cr 250 • Poor kidney function Group 2: • Metformin - CRT • High Cr • Creat high • Cr 250 with chance of lactic acidosis • Creatinine high • Cr - 250 • CRI • Creat 250 Group 3: • Creatinine of 250 • Impaired renal function. • odd, Met + Insulin • HbA1c high, change antiglycemic • metformin in setting of renal impairment • Cr elevated • 30/70 30U BID - hypo? • kidney disease Group 4: • creatinine high • high Cr 250 • High creatinine • elevated creatinine • Creatinine 250 - risk of lactic acidosis • needs insulin fully , A1C • poor renal function • Cr 250 • T1 vs T2 DM? • Does not mention when to take it • Cr too high, 250; metformin contraindicated • Renal function poor (Cr 250) • Cr 250 Group 5:

		• Pt on insulin regimen; other meds? high Cr • Check LFTs • Already on insulin with renal impairment - change to MDI

* Transcribed verbatim from questionnaires, no corrections made (e.g., short forms and abbreviations not expanded).

Table 10: Prescribing Score by Screen Design

Screen Design			**Correct**	**Incorrect**	**Total**
D	H	P	*n (%)*	*n (%)*	*N*
-	-	-	31 (51.7)	29 (48.3)	60
-	-	+	46 (73.0)	17 (27.0)	63
-	+	-	48 (77.4)	14 (22.6)	62
-	+	+	40 (63.5)	23 (36.5)	63
+	-	-	42 (72.4)	16 (27.6)	58
+	-	+	37 (60.7)	24 (39.3)	61
+	+	-	47 (75.8)	15 (24.2)	62
+	+	+	46 (73.0)	17 (27.0)	63
Grand Total:			337 (68.5)	155 (31.5)	492

- 528 responses with 36 missing = 492

Table 11: Correct vs. Incorrect Prescribing Decisions by Screen Design Factor

Screen Design Factor	**Correct** *n (%)*	**Incorrect** *n (%)*	**Total** *N*
Density			
+	172 (70.5)	72 (29.5)	244
-	165 (66.5)	83 (33.5)	248
Highlighting			
+	181 (72.4)	69 (27.6)	250
-	156 (64.5)	86 (35.5)	242
Placement			
+	169 (67.6)	81 (32.4)	250
-	168 (69.4)	74 (30.6)	242
Grand Total:	337 (68.5)	155 (31.5)	492

Table 12: Screen Design and Prescribing Accuracy – Main Effects

Source of Variance			Test of Model Effects		
	β*	Standard Error	Wald Chi-Square	Degrees of Freedom	*p*-value
Main Effects					
Density	0.480	0.333	2.076	1	0.150
Highlighting	0.817	0.256	10.213	1	0.001
Placement	- 0.030	0.266	0.013	1	0.910
Covariates	Wald Chi-Square		Degrees of Freedom		*p*-value
Prescribing scenario	43.533		7		< 0.001
Run order	17.059		7		0.017
Study session	13.466		4		0.009

* Correct decision modeled as the response, with incorrect decision as the reference category, for design factors set at the optimal level (i.e. +)

Table 13: Screen Design and Prescribing Accuracy – Interactions

Source of Variance	Test of Model Effects		
	Wald Chi-Square	Degrees of Freedom	*p*-value
2-way Interactions			
Density * Highlighting	1.662	1	0.197
Density * Placement	0.294	1	0.587
Highlighting * Placement	2.653	1	0.103
3-way Interaction			
Density * Highlighting * Placement	0.015	1	0.903

Table 14: Participants Preferences All Groups by Factors Investigated

Factor Investigated	Prefer Hypothesized Worse Screen *n (%)*	Prefer Hypothesized Better Screen *n (%)*	Total *n*
Density	58 (44.3)	73 (55.7)	131
Highlighting	26 (19.7)	106 (80.3)	132
Placement	65 (49.6)	66 (50.4)	131

Table 15: Participant Preferences All Groups by Paired Comparison

Factor Investigated	Screen 1			Screen 2			Prefer Screen 1 *n (%)*	Prefer Screen 2 *n (%)*	Total *n*	Chi-Square*	*p*-value
	D	H	P	D	H	P					
Density	-	+	+	+	+	+	31 (47.7)	34 (52.3)	65	0.138	0.710
Highlighting	+	-	+	+	+	+	8 (12.1)	58 (87.9)	66	37.879	< 0.001
Placement	+	+	-	+	+	+	34 (51.5)	32 (48.5)	66	0.061	0.806
Density	-	-	+	+	-	+	27 (40.9)	39 (59.1)	66	2.182	0.140
Highlighting	-	-	+	-	+	+	18 (27.3)	48 (72.7)	66	13.636	< 0.001
Placement	+	-	-	+	-	+	31 (47.7)	34 (52.3)	65	0.138	0.710

* Degrees of freedom = 1 for all paired comparisons

Table 16: Participants Preferences by Study Session

Study Session	Factor Investigated	Screen 1			Screen 2			Prefer Screen 1 *n (%)*	Prefer Screen 2 *n (%)*	Total *n*
		D	H	P	D	H	P			
1: SJHH	Density	-	+	+	+	+	+	11 (84.6)	2 (15.4)	13
	Highlighting	+	-	+	+	+	+	1 (7.7)	12 (92.3)	13
	Placement	+	+	-	+	+	+	9 (69.2)	4 (30.8)	13
	Density	-	-	+	+	-	+	11 (84.6)	2 (15.4)	13
	Highlighting	-	-	+	-	+	+	12 (92.3)	1 (7.7)	13
	Placement	+	-	-	+	-	+	8 (61.5)	5 (38.5)	13
2: HGH	Density	-	+	+	+	+	+	6 (46.2)	7 (53.8)	13
	Highlighting	+	-	+	+	+	+	3 (23.1)	10 (76.9)	13
	Placement	+	+	-	+	+	+	7 (53.8)	6 (46.2)	13
	Density	-	-	+	+	-	+	6 (46.2)	7 (53.8)	13
	Highlighting	-	-	+	-	+	+	1 (7.7)	12 (92.3)	13
	Placement	+	-	-	+	-	+	8 (61.5)	5 (38.5)	13
3: MUMC	Density	-	+	+	+	+	+	7 (58.3)	5 (41.7)	12
	Highlighting	+	-	+	+	+	+	2 (16.7)	10 (83.3)	12

	Placement	+	+	-	+	+	+	6 (50.0)	6 (50.0)	12
	Density	-	-	+	+	-	+	3 (25.0)	9 (75.0)	12
	Highlighting	-	-	+	-	+	+	2 (16.7)	10 (83.3)	12
	Placement	+	-	-	+	-	+	6 (50.0)	6 (50.0)	12
4: SFHC	Density	-	+	+	+	+	+	7 (29.2)	17 (70.8)	24
	Highlighting	+	-	+	+	+	+	2 (8.0)	23 (92.0)	25
	Placement	+	+	-	+	+	+	11 (44.0)	14 (56.0)	25
	Density	-	-	+	+	-	+	7 (28.0)	18 (72.0)	25
	Highlighting	-	-	+	-	+	+	3 (12.0)	22 (88.0)	25
	Placement	+	-	-	+	-	+	8 (33.3)	16 (66.7)	24
5: MFP	Density	-	+	+	+	+	+	0 (0.0)	3 (100.0)	3
	Highlighting	+	-	+	+	+	+	0 (0.0)	3 (100.0)	3
	Placement	+	+	-	+	+	+	1 (33.3)	2 (66.7)	3
	Density	-	-	+	+	-	+	0 (0.0)	3 (100.0)	3
	Highlighting	-	-	+	-	+	+	0 (0.0)	3 (100.0)	3
	Placement	+	-	-	+	-	+	1 (33.3)	2 (66.7)	3

- Screen 2 is hypothesized better screen design with factor investigated at +

Table 17: Screen Preferences and Prescribing Accuracy

Paired Comparison*	**McNemar Test Statistics**			
	N	Chi-Square[a]	Asymptotic significance	Exact significance (2-tailed)
P1: – + + vs. + + + (D)	61	0.300	0.584	-
P4: – – + vs. + – + (D)	60	1.091	0.296	-
P2: + – + vs. + + + (H)	60	1.885	0.170	-
P5: – – + vs. – + + (H)	62	0.148	0.700	-
P3: + + – vs. + + + (P)	61	-	-	0.503[b]
P6: + – – vs. + – + (P)	55	-	-	0.078[b]

a. Continuity Corrected

b. Binomial distribution used

* Pairs comparing (D) – density, (H) – highlighting, (P) - placement

Table 18: Study Feedback

Question	Score *mean (SD)*	Total *n*
I was able to fully understand what I was asked to do in this study.	5.4 (1.4)	65
I felt that I had an adequate amount of time to make my prescribing decision when presented with the cases.	4.2 (1.7)	65
Overall, I did not have difficulty completing this study.	4.9 (1.5)	65

Table 19: Participant Comments

Question	Yes *n (%)*	No *n (%)*	Total *n*
Were any of the prescribing cases unclear?	22 (35.5)	40 (64.5)	62
If yes, which cases were unclear?	• Case 6 (S6 cipro and metro for diabetic foot) • Don't remember • Can't remember • Context, was in family office or in hospital? • 4 (S5 digoxin and potassium level) & 11 (S7 risperidone) • Just general unfamiliarity with system • Occasionally could not find reason for why we were prescribing the drug • case 7 (S8 hydromorphone to COPD pt) • most were unclear • cannot recall specifics but mainly those where clinical Hx diff. to identify • cannot remember • Case 6 (S6 cipro and metro for diabetic foot) • can't recall • Unsure. (statins, small rise in AST, ALT) • can't recall • several, cannot remember • Most, as I was unaware of this assessment I was not sure what to do and found it a bit irrelevant to prescribing online system • Most of them, limited time and small font size		18
Is there anything you would change about this study?	22 (35.5)	40 (64.5)	62
If yes, what	• Increase time per case		

would you change?	• More time • Can give slightly more time to answer, and use same format for all cases • Trial runs before actually doing studied cases • Might be helpful to use one kind of EMR screen so can at least see all the info, then decide from there • Setting, visit date to correlate findings • Possibly a few practice cases prior to case 1 • Perhaps a brief description of each patient/visit circumstances prior to prescribing screen would put it more into context. As a physician using this system you would have completed a H/P. • Bigger screen, longer time for making decisions • 1st slide was confusing whether it was 1st case • Few more seconds to make Rx decision. • More time for each case (to gather all info) • More time, a few practice scenarios, more consistent images from case to case (re: info) • Was confused about the number of each cases • Would be much more valid if we were able to sit in front of a computer screen each. • Giving more time per case (1 min would be better) • I think there are a lot of confounding factors and conclusions cannot be made just based on a screen, because when making decisions we have the ability to clarify information • Maybe a few less cases. A lot of prescribing decisions are based on a case-by-case basis. Ex. - I may still prescribe a statin if a pt had slight elevation in LFTs, depending on clinical context • If you can provide paper version of cases or each participant can each use computer - it was difficult to see most of the cases - it made it difficult to answer the question. • Some prior clear indication on completing this assessment. I would also suggest having an online assessment utilizing one of the computer rooms at McMaster and individuals completing this survey can complete it on a computer one on one and this makes the assessment more practical and realistic. • Time and font size • I could have used more time to process info - can't pick out the needed info.	

Table 20: Additional Participant Comments

Study Session	Additional Comments*
1: SJHH	• Very practical and useful study. Well done.
2: HGH	• Difficult for a clerk to Dx and Tx in 45 seconds! • Fun and interactive
3: MUMC	• Interesting concept and study
4: SFHC	• Should clarify again/better where to find if a certain medication has been Rx before • Took a lot of time to find information in cases in screen with too little time for cases. • A bit arbitrary to decide screen layout preference when viewing for few seconds, vs. using all day/every day • Interesting study. Colour is better for EMR templates. • 1) There are two assessments here; a) the script program and b) the physician. And the responses of the survey could be biased due to one of two factors or both (for e.g. the system is right but the physician missed something or vice versa). 2) Limitation of screen, all information to consider may not be on just one screen.

* 9 of the 66 respondents provided additional comments

Appendix 1: Literature Search Strategies and Results

Search Strategies:

Database: **Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily and Ovid MEDLINE(R)** (1946 to Present)	
Search strategy:	**Date of search: 05/09/2014**
1. exp Electronic Prescribing/ 2. exp Medical Records Systems, Computerized/ 3. exp Medical Order Entry Systems/ 4. exp Hospital Information Systems/ 5. exp Medical Records/ 6. exp Electronic Health Records/ 7. exp Decision Making, Computer-Assisted/ 8. exp Decision Support Systems, Clinical/ 9. (e-prescribing or electronic prescribing or prescribing electronic* or CPOE or order entry or electronic medical record* or electronic health record*).ti,ab. 10. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 11. exp User-Computer Interface/ 12. exp Software Design/ 13. exp Human Engineering/ 14. (usability or user test* or user-test* or user interface* or interface* or human factors).ti,ab. 15. 11 or 12 or 13 or 14 16. exp Randomized Controlled Trial/ 17. exp Random Allocation/ 18. exp Cross-Over Studies/ 19. (random* or cross-over or crossover).ti,ab. 20. 16 or 17 or 18 or 19 21. 10 and 15 and 20	
Records Retrieved	539

Database: **Embase** (1974 to Present)	
Search strategy:	**Date of search: 05/09/2014**
1. exp electronic prescribing/ 2. exp computerized provider order entry/ 3. exp hospital information system/ 4. exp medical information system/ 5. exp medical record/ 6. exp electronic medical record/ 7. exp decision support system/ 8. (e-prescribing or electronic prescribing or prescribing electronic* or CPOE or order entry or electronic medical record* or electronic health record*).ti,ab. 9. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 10. exp computer interface/ 11. exp computer graphics/ 12. exp human computer interaction/ 13. exp human factors research/	

14. (usability or user test* or user-test* or user interface* or interface* or human factors).ti,ab. 15. 10 or 11 or 12 or 13 or 14 16. exp randomized controlled trial/ 17. exp randomization/ 18. (random* or cross-over or crossover).ti,ab. 19. 16 or 17 or 18 20. 9 and 15 and 19	
Records Retrieved	194

Database: **PsycINFO** (1987 to Present)	
Search strategy:	**Date of search: 05/14/2014**
1. exp Decision Support Systems/ 2. exp Information Systems/ 3. exp Medical Records/ 4. (e-prescribing or electronic prescribing or prescribing electronic* or computerized provider order entry or CPOE or hospital information system* or medical information system* or decision support system* or computerized decision support or CDSS or order entry or electronic medical record* or electronic health record*).ti,ab. 5. 1 or 2 or 3 or 4 6. exp Human Computer Interaction/ 7. exp Human Factors Engineering/ 8. exp Systems Design/ 9. (usability or user test* or user-test* or user interface* or interface* or human factors).ti,ab. 10. 6 or 7 or 8 or 9 11. (random* or cross-over or crossover).ti,ab. 12. 5 and 10 and 11	
Records Retrieved	137

Database: **Full Text Journals @Ovid**	
Search strategy:	**Date of search: 05/16/2014**
1. (e-prescribing or electronic prescribing or prescribing electronic* or computerized provider order entry or CPOE or hospital information system* or medical information system* or decision support system* or computerized decision support or CDSS or order entry or electronic medical record* or electronic health record*).mp. [mp=title, abstract, full text, caption text] 2. (usability or user test* or user-test* or user interface* or interface* or user-computer interface or user computer interface or human factors or human-computer interaction or human computer interaction).mp. [mp=title, abstract, full text, caption text] 3. (random* or cross-over or crossover).mp. [mp=title, abstract, full text, caption text] 4. 1 and 2 and 3	
Records Retrieved	584

Database: **Journals @ScholarsPortal**	
Search strategy:	**Date of search: 05/20/2014**

1. usability OR interface OR interfaces 2. randomized OR randomly OR random 3. electronic prescribing OR e-prescribing OR order entry OR decision support OR electronic medical record OR electronic health record OR electronic medical records OR electronic health records 4. 1 and 2 and 3 5. Limit 4 to Subject Areas: Engineering, Health Sciences, Information Technology, Library and Information Sciences, Life Sciences, Medical Sciences, Social Sciences, Telecommunications Technology gives	
Records Retrieved	1642

Summary of Searches:

Search	
Total no. retrieved:	3096
Medline:	539
Embase:	194
PsycInfo:	137
Full Text Journals @Ovid:	584
Journals @ Scholars Portal:	1642
Duplicates:	205
Total no. without duplicates:	2891
Screening (Title and Abstract Review)	
No. excluded:	2854
Included for full text review:	37
Selection (Full Text Review)	
No. Excluded:	21
Reasons for exclusions:	
1. Conference abstract (2) 2. Study protocol (1) 3. Did not evaluate system usability or user interface (5) 4. Non-clinician study participants (3) 5. Compared electronic tool versus paper (2) 6. Did not use randomization in study design (7) 7. Did not use a control tool or interface in study design (1)	
Included:	16

Summary of Included Studies:

Study	Participants, Sample Size	Study Design and Randomization Method	Intervention	Control	Outcomes Measured
Crossover and Experimental Studies with Randomization					
Ahmed et al. 2011	20 off-duty ICU physicians	Randomized crossover study with participants randomized to complete a standardized task (answering a set of questions) with 4 patients' data using intervention or control user interface, then crossed over to the other interface to complete task with 4 more patients' data.	Novel user interface EMR presenting and grouping frequently utilized data on a single screen in systems based manner most commonly encountered in ICU setting (developed based on systematic observation and analysis of ICU provider needs)	Standard EMR with required data presented on multiple screens	1. Physician task load index (measured with NASA task load index) 2. Errors of cognition 3. Time to task completion (in seconds) 4. Total quantity of data presented
Avansino & Leu 2012	7 surgeons at pediatric hospital	Randomized crossover study with participants block-randomized (in groups of 4) to use intervention or control order sets to complete 2 clinical scenarios (perforated and nonperforated appendicitis), with washout period of 4 hours minimum, followed by use of other order set to complete the clinical scenarios.	Systematically developed order set for postoperative appendicitis with review by multidisciplinary team	Ad hoc developed order set	1. Physician task load index (measured with NASA task load index) 2. Order set usability measured with System Usability Scale (SUS) 3. Time spent 4. Click counts 5. Number of free text orders required
Bauer et al. 2010	12 physicians from academic medical centre	Experimental design with repeated measures. Participants presented with 4 patient data cases on one display, followed by slightly altered versions of the same 4 cases on the other display. Case order randomized for first display type viewed, and deliberately set according to rule for second display type.	Graphical display of laboratory data	Table display of laboratory data	1. Time to complete case 2. Interpretation of case

Bostrom et al. 2011	12 participants comprising of trainees and staff urologists	Crossover study with participants randomized to complete one clinical scenario using intervention or control, then crossed over to complete a second clinical scenario using the other system.	*eCancerCare*^{Bladder} system developed with input and consensus from clinicians, specific for patients with bladder cancer, which included features such as color-coded icons that provide clinically significant results, and visual timeline display of data	Standard electronic patient record	1. Time to complete chart review and produce clinical report 2. Quality of clinical report using predetermined quality parameters 3. Accuracy of answers about patient's history 4. User satisfaction assessed with questionnaire
Chan et al. 2011	27 participants comprising of staff physicians, residents and medical students	Experimental design with repeated measures. Participants completed four ordering tasks using intervention and control interfaces, with randomization of the order of interfaces and the ordering tasks presented.	User centred design prototype CPOE order set interface (developed based on heuristic usability evaluation)	1. Standard CPOE order set system 2. Pre-printed paper order set forms	1. Time to complete order set 2. Number of times participants requested assistance 3. Errors in submitted orders
Doig et al. 2011	15 critical-care nurses and 15 nursing students	Crossover study with participants randomized to complete a standardized task (answering a set of questions) using intervention or control, then crossed over to complete the task using the other display.	Graphical display of arterial blood gas data	Numerical display of arterial blood gas data	1. Accuracy of answers to standardized task 2. Response time for correct answers 3. Task load index (measured with NASA task load index) 4. Usability and subjective evaluation, assessed with survey
Khajouei et al. 2010	10 physicians (1 attending and 9 residents) in hematology/ oncology department	Crossover study with participants randomized to complete a clinical scenario using intervention or control, then crossed over to complete the same clinical scenario using the other interface.	CPOE interface with predefined order sets	CPOE interface without predefined order sets (i.e. ordering medications one by one)	1. Excess number of mouse clicks and keystrokes (the difference between number of mouse clicks and keystrokes used and the minimally required numbers to accomplish

					the ordering tasks) 2. Frequency of usability problems identified through observation by usability experts
Koch et al. 2013	12 burn trauma ICU nurses	Crossover study with participants randomized to answer 3 clinical scenarios using intervention or control, then crossed over to complete the same clinical scenarios using the other display on a separate day within a week's time.	Integrated information display prototype (paper booklet mockup) with information on 14 pages such as scheduled and current medication, vital signs, ventilator settings, fluid balance and temperature, and recently changed settings and orders highlighted (developed based on user-centred approach and user testing with ICU nurses)	Traditional displays (paper booklet mockup) with information on 31 pages	1. Accuracy of responses for clinical scenarios 2. Time to complete task
Lamy et al. 2008	11 general practitioners	Experimental design, with participants asked to answer medical questions about fictitious drug monographs presented on intervention or control interface, with randomization of the order of interfaces and order of questions presented.	Graphical interface based on anatomical diagram of human body displaying excerpts from drug monograph (e.g. drug properties, contraindications, adverse effects) through interactive icons	Textual interface to display drug monograph information	1. Accuracy of responses to questions 2. Time to complete responses 3. User satisfaction
Marian et al. 2012	60 anesthesia residents, anesthesiolog-ists, and certified registered nurse anesthetists	Experimental design, with participants asked to enter medications from a list of 25 using intervention or control interface, with random assignment to the first interface viewed and medication order set deliberately.	Medication buttons arranged by categories (e.g. tabs labelled fluids & electrolytes, coagulation, antibiotics, etc.) in simulated anesthesia information management system	Medication buttons arranged alphabetically (e.g. tabs labelled A-C, D-H, I-O and P-Z) in simulated anesthesia information management system	1. Number of medications entered in 2-minute time span 2. Entry errors

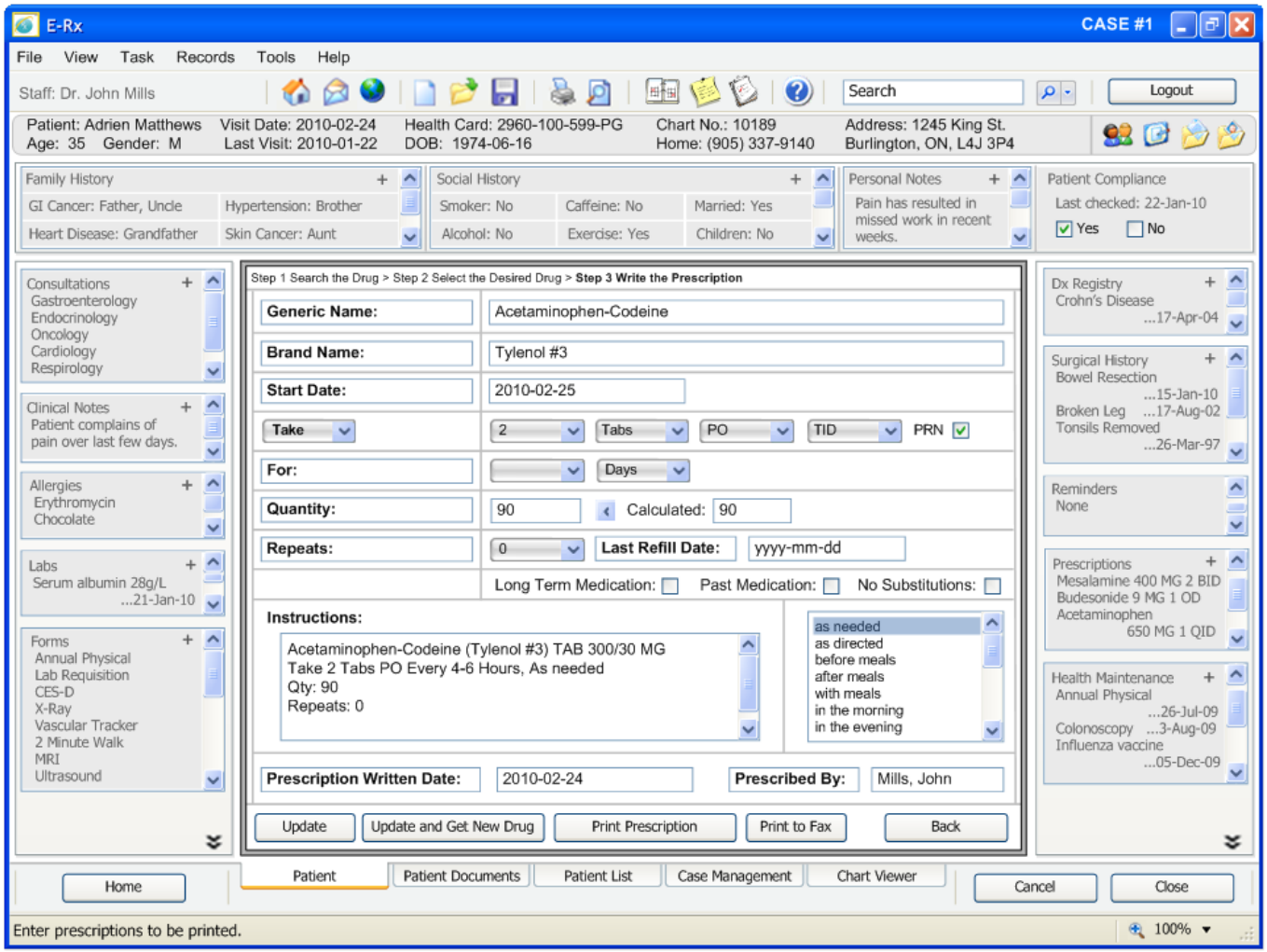
Saleem et al. 2007	16 ambulatory clinic nurses	Experimental design, with participants assigned to complete 5 simulated clinical scenarios using intervention or control interface, then complete 5 similar scenarios with the other interface. Order of presentation of interfaces was counter-balanced (e.g. participant 1 viewed intervention first, participant 2 viewed control first, etc.) and order of scenario presentation was randomized.	Redesigned clinical reminder system prototype, with reminders labeled for nurse or physician, dialog box accessible via single click from main page, dialog box format standardized, and an electronic visit checklist (developed based on usability principles and findings from previous studies)	Standard Veterans Health Administration (VHA) clinical reminder system	1. Time to complete clinical reminder 2. Usability, assessed with questionnaire 3. Task load index (measured with NASA task load index)
Tsopra et al. 2014	38 general practitioners	Crossover study with participants randomized to answer one set of clinical cases using intervention or control, then crossed over to complete a second set of clinical cases using the other interface. Clinical cases for each set selected through stratified random sampling from a pool of 150 cases, and participants were randomized to first view intervention or control interface.	'At-a-glance' interface (developed according to usability principles) displaying decision support for antibiotics (based on clinical practice guideline) in a decision table and segmented graphical display, including recommended actions highlighted in intuitive colours	'Expand-contract interface' displaying decision support for antibiotics (based on clinical practice guideline) in a hierarchical tree that requires clicking through levels	1. Perceived usability, measured with System Usability Scale (SUS) 2. Accuracy of responses for clinical scenarios (considered correct if matching action recommended in guideline) 3. User confidence level measured with 4-point Likert scale
Randomized Controlled Trials					
Del Fiol et al. 2008	104 clinicians at hospitals and clinics of Intermountain Healthcare	RCT with matched participants (according to median session duration and total number of sessions during pre-study period) randomized to intervention or control interface for patient care and order entry.	Topic-specific links ("Infobuttons") in EMR order entry module to common information needs (e.g. adult dose)	Nonspecific links in EMR order entry module that displayed a drug summary document, requiring users to browse and scroll to find the topic of	1. Session duration (i.e. time spent seeking information using the link) 2. Number of sessions (i.e. frequency of use of links) 3. Positive or negative impact of session, assessed with survey of

				interest	participants
Hettinger & Fairbanks 2012	46 emergency medicine providers at academic medical centre	RCT with participants randomized to one of three different simulated radiology CPOE interfaces (programmed to cause patient selection error) to complete 3 clinical scenarios.	1. CPOE interface with patients' names bolded with increased font size and unique colour 2. CPOE interface patients' names bolded with increased font size and unique colour and additional contextual information (e.g. location and chief complaint)	Simulation of standard CPOE system interface	1. Recognition of patient selection error 2. Stage in which patient selection error was recognized 3. Time interval from selection of wrong patient to recognition of error
Rosenbloom et al. 2005	148 house staff on 7 study wards at Vanderbilt University Hospital	RCT with house staff randomized in clustered blocks during monthly rotations to use intervention or control interface for patient care and order entry.	Placement of decision support content links directly in the user interface, with highlighting of active links when opportunities for relevant decision support were available	Access to decision support content on separate page through "Bells and Whistles" link	1. Access to the decision support feature 2. Mean estimated expenditures per order entry session
Scheepers-Hoeks et al. 2013	902 alerts for 384 ICU patients, treated by 10 physicians	RCT with patients admitted to ICU assigned to intervention or control methods of alerting in CDSS, with 4 methods based on the same clinical rules and providing same information.	1. Pop-up alert in EHR window 2. Alerts displayed when 'CDSS tab' in EHR clicked 3. Physician alert list, with Excel document of alerts placed on electronic desktop of physicians 4. Pharmacy intervention, with Excel document of alerts placed on electronic pharmacy desktop, and subsequent consultation with ICU physician	n/a	1. Compliance (within 24 hrs) with recommendation generated by alert 2. Physician user satisfaction survey

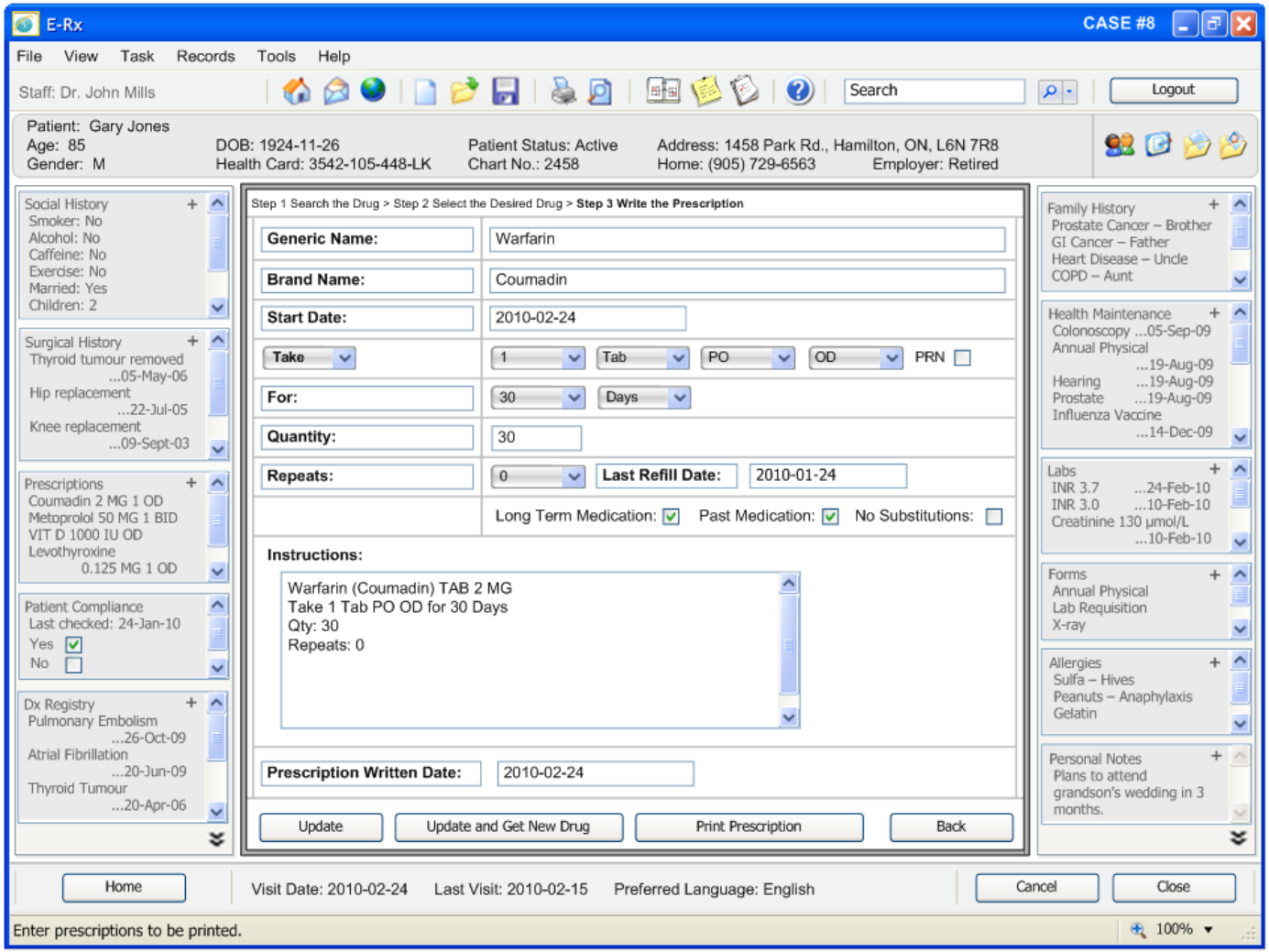
Appendix 2: e-Prescibing System User Interface Configurations

Note: The order of factors represented by the symbol (i.e. - - -, + + +) is density, highlighting, placement.

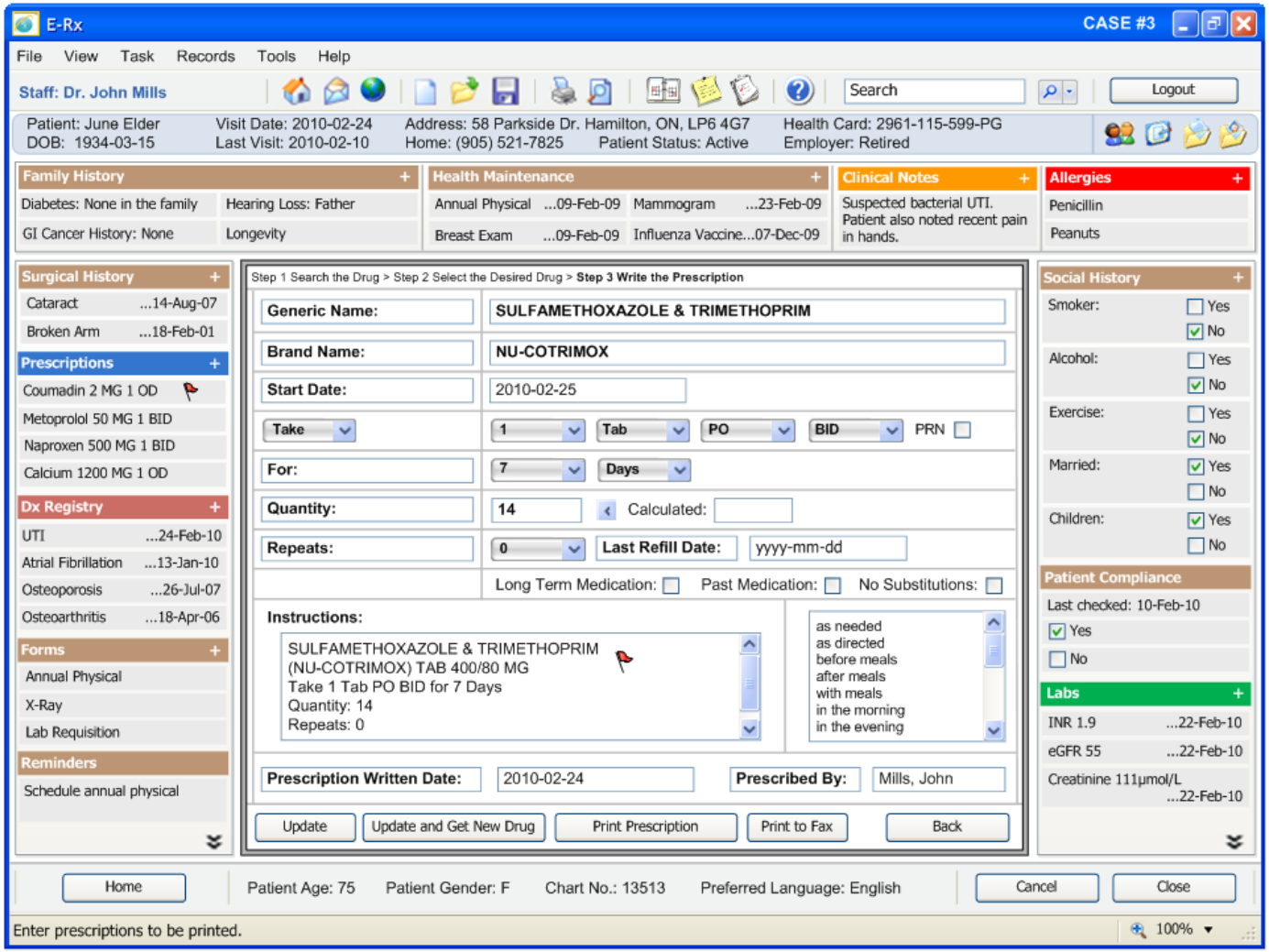
1. Screen Design: - - -



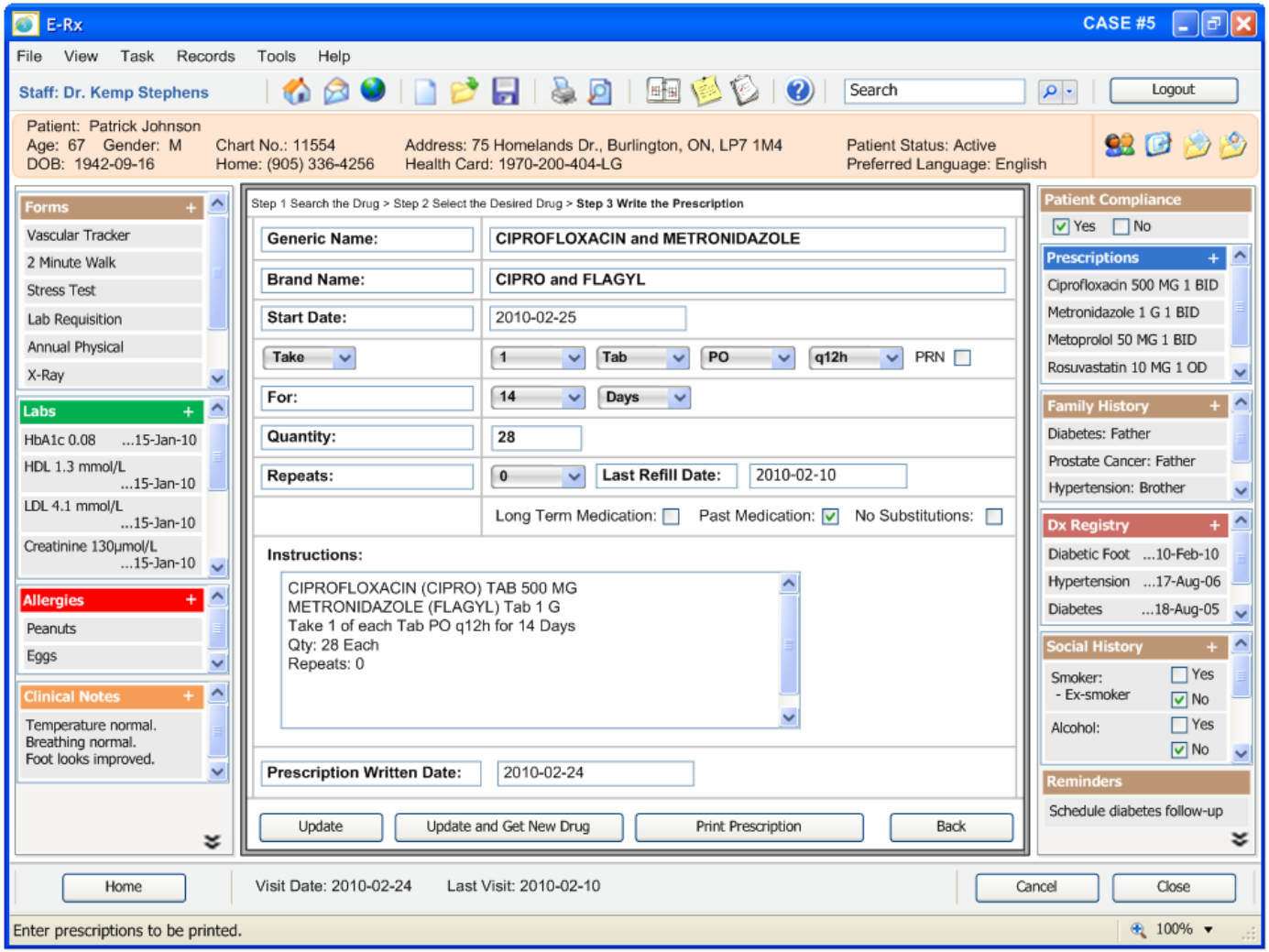
2. Screen Design: + - -



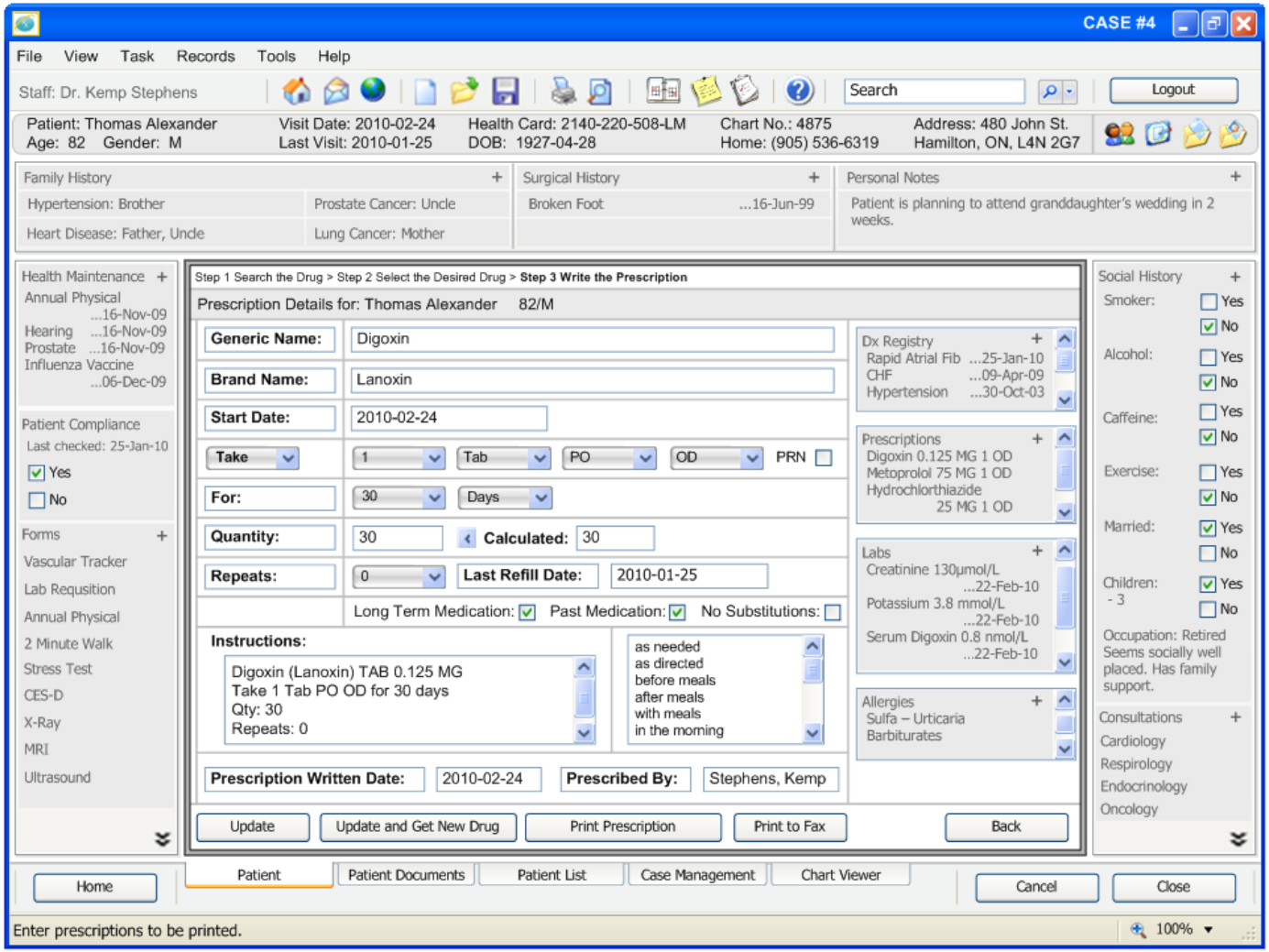
3. Screen Design: - + -



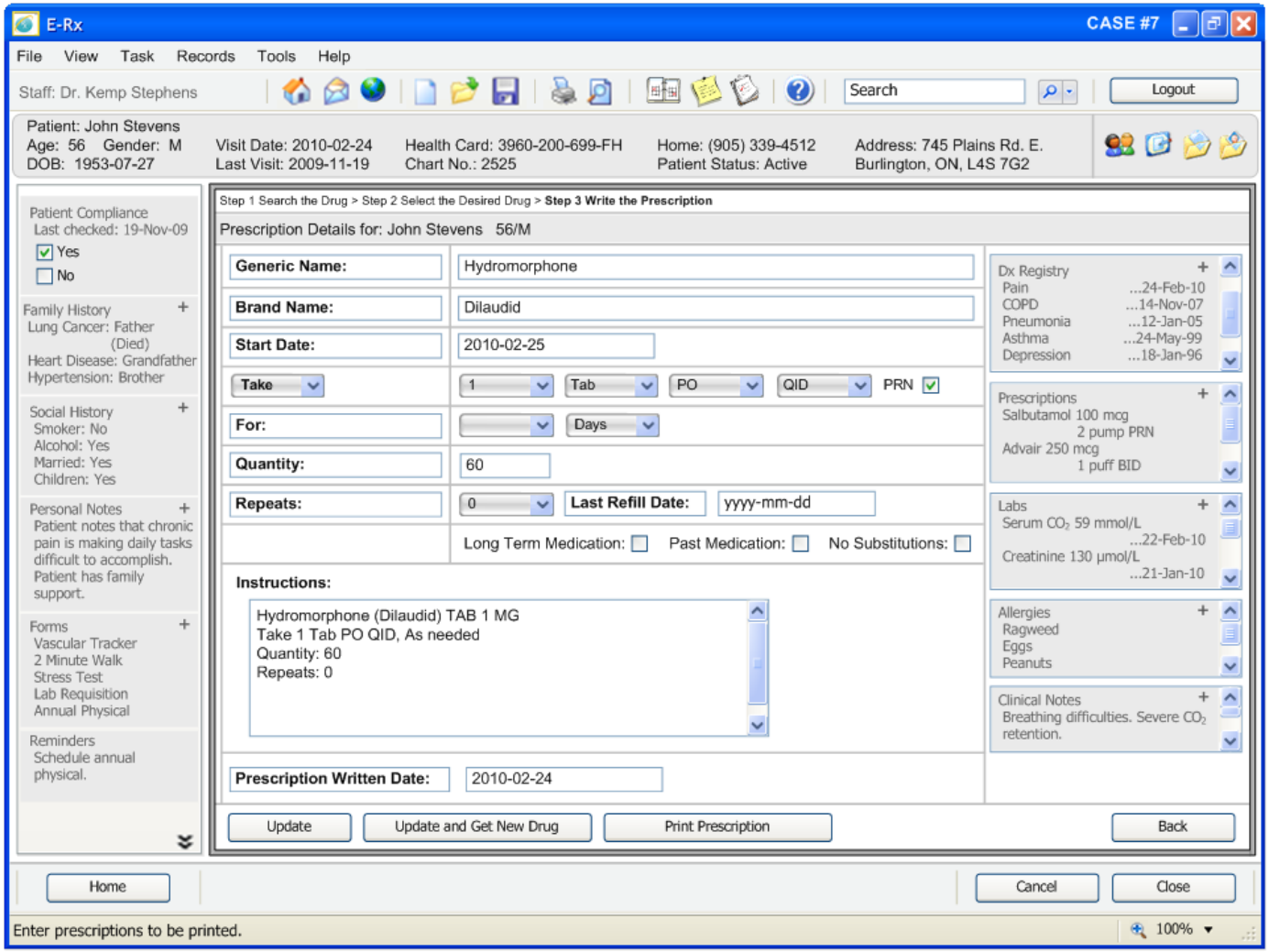
4. Screen Design: + + -



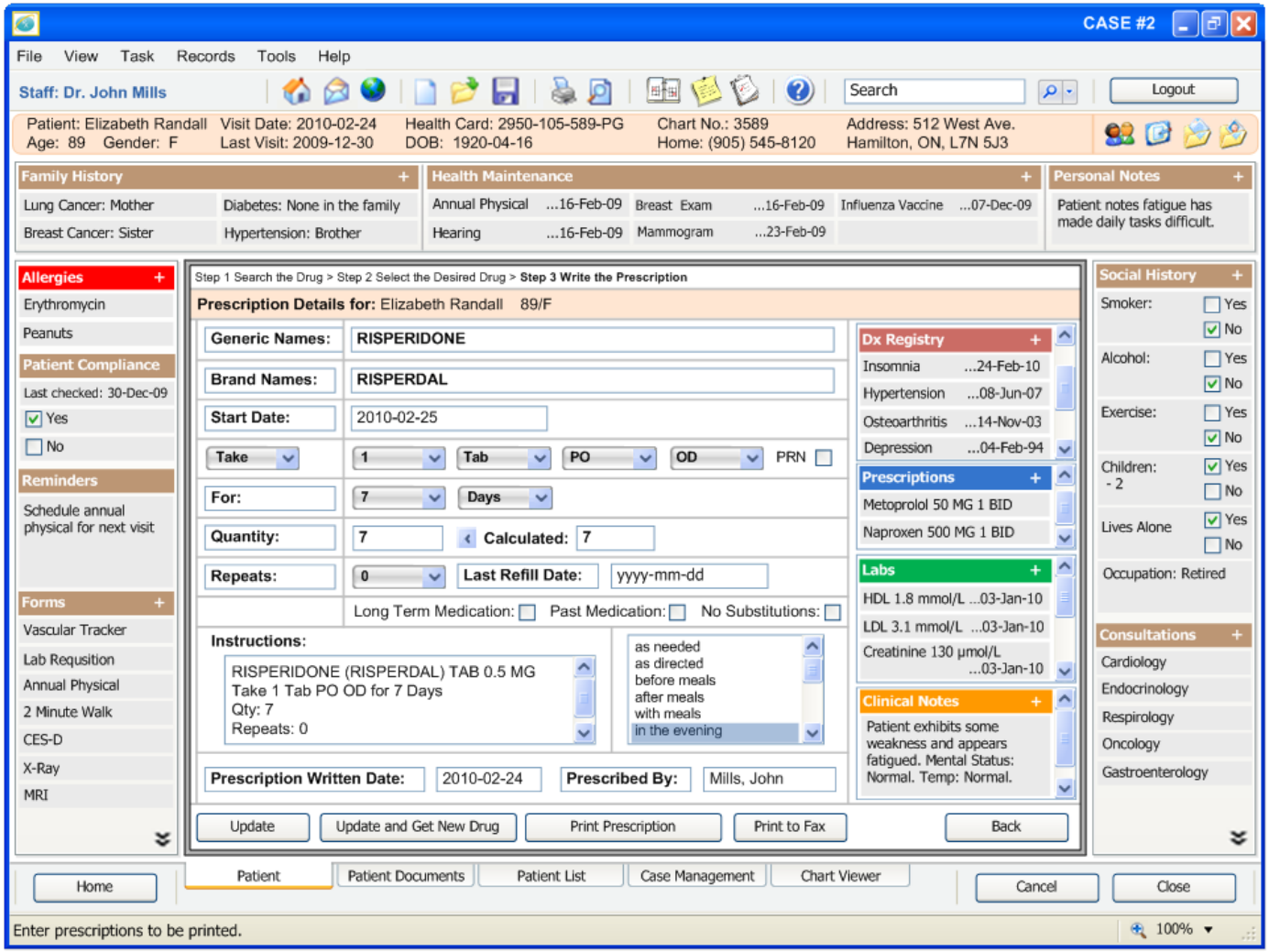
5. Screen Design: - - +



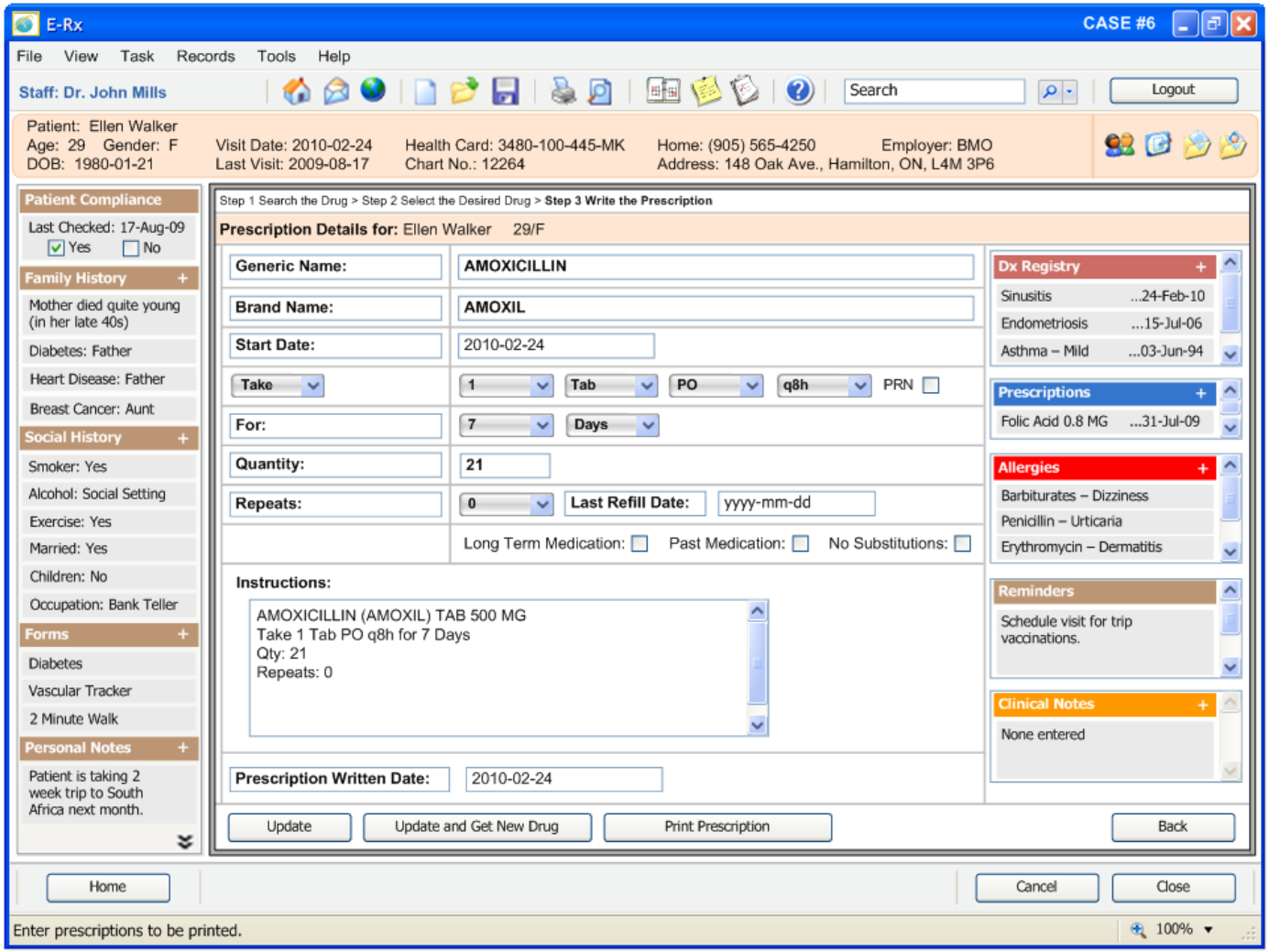
6. Screen Design: + - +



7. Screen Design: - + +



8. Screen Design: + + +



Appendix 3: Questionnaire with Scoring

Centre for Evaluation of Medicines

PRESCRIBING USING AN ELECTRONIC PRESCRIBING SYSTEM: QUESTIONNAIRE

CONSENT STATEMENT

You are being invited to participate in a research study that will investigate prescribing using electronic prescribing systems. You have been given an introduction to the study and have been informed about the study purpose and what is being asked of you as a participant by the research staff. By completing the questionnaire, you consent to the anonymous data collected to be used for the research study and to be summarized in publication.

---

1. Have you participated in this study before?
   - ☐ Yes (1)
   - ☐ No (0)

2. What is your level of training?
   - ☐ Clerkship (7)
   - ☐ Attending Physician (8)
   - Other (9)
   - ☐ PGY 1 (1)
   - ☐ PGY 4 (4)
   - ☐ PGY 2 (2)
   - ☐ PGY 5 (5)
   - ☐ PGY 3 (3)
   - ☐ PGY 6 (6)

3. What is your area of specialty?:

   _____

   IM = 1; FM = 2; Emergency Medicine = 3; Radiation Oncology = 4; Orthopedics = 5; Ob/Gyn = 6; Pharmacy Resident = 7

4. Imagine yourself as the physician about to make a prescribing decision. With each electronic prescribing system screenshot presentation, please evaluate the information on the screen and state whether you would or would not prescribe the selected drug(s) for the patient:

		Scenario	Screen (D/H/P)
Case 1:	☐ Prescribe (0) ☐ Do not Prescribe (1)	Scenario 3	- + -

Reason: _____

Case 2: ☐ Prescribe (1) ☐ Do not Prescribe (0) Scenario 5 + - -

Reason: _____

Case 3: ☐ Prescribe (0) ☐ Do not Prescribe (1) Scenario 4 - + +

Reason: _____

Case 4: ☐ Prescribe (1) ☐ Do not Prescribe (0) Scenario 1 + + -

Reason: _____

Case 5: ☐ Prescribe (0) ☐ Do not Prescribe (1) Scenario 7 + - +

Reason: _____

Case 6: ☐ Prescribe (1) ☐ Do not Prescribe (0) Scenario 6 - - +

Reason: _____

Case 7: ☐ Prescribe (0) ☐ Do not Prescribe (1) Scenario 8 + + +

Reason: _____

Case 8: ☐ Prescribe (0) ☐ Do not Prescribe (1) Scenario 2 - - -

Reason: _____

Case 9: ☐ Prescribe (1) ☐ Do not Prescribe (0) Scenario 10 - + + (factor duplicate of C3)

Reason: _____

Case 10: ☐ Prescribe (0) ☐ Do not Prescribe (1) Scenario 12 + + + (factor duplicate of C7)

Reason: _____

Case 11: ☐ Prescribe (1) ☐ Do not Prescribe (0) Scenario 5 + - - (exact duplicate of C2)

Reason: _____

Case 12: ☐ Prescribe (0) ☐ Do not Prescribe (1) Scenario 11 + - + (factor duplicate of C5)

Reason: _____

Case 13: ☐ Prescribe (1) ☐ Do not Prescribe (0) Scenario 9 - + - (factor duplicate of C1)

Reason: _____

Case 14: ☐ Prescribe (0) ☐ Do not Prescribe (1) Scenario 4 - + + (exact duplicate of C3)

Reason: _____

5. You will be shown electronic prescribing system screenshots in pairs. Please evaluate the presentation of the interface in each screenshot and indicate for each pair which screen you prefer (the one on your left or on your right, facing the screen):

		L. Screen (D/H/P)		R. Screen (D/H/P)	Factor
i.	☐ Left (0) ☐ Right (1)	+ - -	vs	+ - +	P
ii.	☐ Left (1) ☐ Right (0)	+ + +	vs	+ + -	P
iii.	☐ Left (1) ☐ Right (0)	+ + +	vs	- + +	D
iv.	☐ Left (0) ☐ Right (1)	+ - +	vs	+ + +	H
v.	☐ Left (1) ☐ Right (0)	- + +	vs	- - +	H
vi.	☐ Left (1) ☐ Right (0)	+ - +	vs	- - +	D

Study Feedback

6. I was able to fully understand what I was asked to do in this study:

(1)	(2)	(3)	(4)	(5)	(6)	(7)
☐	☐	☐	☐	☐	☐	☐
Strongly Disagree			Neutral			Strongly Agree

7. I felt that I had an adequate amount of time to make my prescribing decision when presented with the cases:

(1)	(2)	(3)	(4)	(5)	(6)	(7)
☐	☐	☐	☐	☐	☐	☐
Strongly Disagree			Neutral			Strongly Agree

8. Overall, I did not have difficulty completing the study:

(1)	(2)	(3)	(4)	(5)	(6)	(7)
☐	☐	☐	☐	☐	☐	☐
Strongly Disagree			Neutral			Strongly Agree

9. Were any of the prescribing cases unclear?

☐ Yes (1)

☐ No (0)

If yes, which cases were unclear (use case numbers from above): _____

10. Is there anything you would change about this study?

☐ Yes (1)

☐ No (0)

If yes, what would you change: _____

_____

Additional Comments: _____

_____

_____

_____