

# COMPUTERIZED PRESCRIBER ORDER ENTRY MEDICATION SAFETY (CPOEMS)

UNCOVERING AND LEARNING FROM ISSUES  
AND ERRORS

Brigham and Women's Hospital  
Harvard Medical School  
Partners HealthCare



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## EXECUTIVE SUMMARY

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The increasing adoption of electronic prescribing—called computerized prescriber order entry (CPOE)—creates opportunities to enhance patient safety but also has potential for introducing new types of prescribing errors.<sup>1</sup> The U.S. Food and Drug Administration (FDA) has funded Brigham and Women’s Hospital (BWH) Center for Patient Safety Research and Practice to conduct an exploration of CPOE-related potential for errors in prescribing, particularly as these relate to drug name displays, and ordering and workflow design issues. The project investigates ways to better identify, understand, and prevent electronic ordering errors in the future.

This White Paper reports on the findings of the BWH FDA Computerized Prescriber Order Entry Medication Safety (CPOEMS) Project which assembled a team of investigators experienced in health information technology (HIT) safety and developed the requisite infrastructure and tools to collect and analyze data to accomplish the key aims of the FDA task order:

**Task 1 - CPOE Descriptions and Modifications:** description and investigation of 18 elements of interest to identify issues in CPOE ordering, display, and workflow.

**Task 2- Identification of Medication Errors:** identification, collection, and analysis of CPOE-related medication errors and opportunities for improvement of CPOE systems, with a focus on product names and CPOE systems vulnerability.

**Task 3 - Summary of Methods and Findings:** including a formal presentation to the FDA in November 2014 and this written White Paper

In **Year 1**, the CPOEMS Project assessed ten systems across six healthcare organizations or “sites”, including both inpatient and outpatient settings and both commercial and home-grown systems. We collated data on these CPOE systems regarding areas of interest to the FDA concerning the systems’ origin, age, history of modification, and functionalities, including search, display, ordering, and clinical decision support. This brought to light myriad issues relating to CPOE system design, implementation, and patterns of use. While some were familiar, many unexpected findings were uncovered—findings that underscore the need for and value of ongoing systematic evaluation of CPOE systems.

In **Year 2**, we developed a multifaceted approach to identify sources of information on CPOE-related errors at BWH and collaborating sites. We then assembled and analyzed this data to identify issues that pose risks for medication errors related to CPOE features. Finally, we present recommendations to address a number of the issues we uncovered as well as create safer systems for identifying and learning from CPOE-related medication patient safety problems based on those findings.

To standardize the assessments, the BWH team iteratively developed the **CPOEMS Assessment Tool (CAT)** with feedback from FDA staff and site coordinators (Appendix B). Test-patient criteria were also developed to help standardize the system assessments.

For Task 1, we carried out a **systematic evaluation of the ten CPOE systems** at the six sites via a seven-step process, including site planning meetings, web-conference viewing and recording of CPOE systems, observation of regular (daily) users of the system using fictitious test patients, and site visits to interview system users and leaders to further study the CPOE systems. Written and visual records were analyzed to determine issues, identify missing data, and finally produce the Task 1 report.

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<sup>1</sup> FDASIA Health IT Report: Proposed Strategy and Recommendations for a Risk-Based Framework. Food and Drug Administration, Federal Communications Commission, Office of the National Coordinator for Health Information Technology. April 2014. [http://www.healthit.gov/sites/default/files/fdasiahalthitreport\\_final.pdf](http://www.healthit.gov/sites/default/files/fdasiahalthitreport_final.pdf)

## EXECUTIVE SUMMARY

In Task 2, we investigated potential CPOE-related errors in more detail by identifying potential data sources at each site for review by the BWH team of clinicians, pharmacists, and informatics experts. A comprehensive investigation including collection of new primary data was undertaken at BWH. Readily available data from collaborating sites were also collected and analyzed. Thus, we cast a broad net looking to uncover sources of information of CPOE safety and errors. These included:

- a. Safety and adverse event reports
- b. Alert override, acceptance, and firing rates
- c. Pharmacy intervention logs
- d. Health information technology (HIT) feedback and redesign reports
- e. Clinical decision support (CDS) inventories
- f. Institutional safety newsletters
- g. Medication safety committee meeting minutes
- h. Institutional root-cause analyses
- i. Special CPOE-related error studies
  - i. Medications discontinued with reason given as “Error (Erroneous Entry)” at BWH
  - ii. Voided medication data (at another site)
  - iii. Duplicate active brand-generic medications order data (BWH)

These data were obtained and reviewed in two phases: (1) by research assistants and pharmacists and then (2) by the full BWH CPOEMS clinical, informatics, and safety team. The BWH MedMarx Taxonomy from a previous study was utilized and further refined to describe and classify the types of errors found (Appendices C and D). The data were then summarized and synthesized to describe major trends in types of medication-related CPOE errors across the sites.

We incorporated data from CPOE system evaluations and interviews conducted during the Task 1 activities that used the CAT to test and directly observe features, functionalities, and other characteristics that could contribute to medication errors (Appendix B). Idiosyncratic system characteristics and behavior were identified throughout the project. Finally, a functionality test using test cases was designed to further investigate whether a functionality issue was unique to certain systems, or seen across sites (Appendix E).

## A. CPOE SAFETY - FINDINGS AND ISSUES

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### CPOE SEARCH, DISPLAY, ORDERING, AND WORKFLOW

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Throughout our research, we found substantial variability in CPOE displays, functionality, and workflow. This variation was apparent at every level: between sites, within sites (e.g., differences between inpatient and outpatient CPOE at a particular hospital), and within single systems (e.g., differences between ordering two different drugs in the same system).

#### 1. DRUG SEARCHING: FINDING THE DESIRED DRUG

Prescribers often encountered problems finding the medication they were trying to order. Search functions differed across the systems, and users were sometimes unaware of the various ways that drugs could be listed in their system(s). This suggests that CPOE search functions need to be more intuitive and consistent across systems. Examples include:

##### **Problems using search function/tool to find intended drug**

These problems are due to a host of issues including inability to search on brand name or text strings, unfamiliarity with searching features (such as “begins with” vs. “contains”), not knowing the programmed

“order” of the ingredients in a combination product, and being overwhelmed with an excessive number of results, which include lab orders.

**“Auto-complete” for drug names and sigs**

Despite their convenience, auto-complete and auto-fill introduce vulnerability, including selecting the wrong drug and overlooking the correct or preferred drug. When applied to order sentences (pre-written medication orders with dose, route, frequency, etc.) or sigs (directions in prescription order), auto-fill may increase efficiency, but be offset by the difficulty of editing and the overall expense of creating such aids.

**2. DISPLAY OF MEDICATIONS**

**Encumbering medication field names with other features or verbiage**

There were several examples of additional descriptors or indications being included within the drug name field to assist prescribers. We felt that tampering with this field was a marker for needed but missing decision support and design features such as formulary support or ordering-by-indication. While the indication information in the name field may be helpful to the prescriber, corrupting the structured drug name field with other verbiage introduced potential for confusion or new errors.

**Truncation of medication names and character limitations**

Medication names are sometimes truncated due to field-width constraints, which vary by monitor size, screen resolution, and window size. If important details that might affect decisions are truncated, medication errors can result. Attempts to avoid truncation included wrapping the drug name to the next line, increasing the character limit, or providing the full drug name when the user hovers the cursor over the truncated name.

**Suffixes and other modifiers**

Across systems, drug name modifiers (e.g., double strength, extended release, etc.) appeared primarily at the end of the drug name. However, there was considerable inconsistency in how the name and its modifiers were displayed (e.g., use of capital letters, character limits, truncation, and word-wrapping).

**Medication concepts**

The display of medication concepts and attributes (e.g., dosage form) is intended to help prescribers select the correct drug formulation; however, the attributes often get truncated, causing confusion and selection of the wrong product. An area that needs further evaluation is how to make the displayed data correspond to the user’s workflow and decision making for selecting the correct medication.

**Items in dropdown lists not initially visible**

In one outpatient system, modifiers appear at the end of the drug name, but the numerical ordering of the doses in the drug list is inconsistent, and the highest doses available are not always listed at the top. For example, when “ferrous sulfate” was searched in one system, an overwhelming 191 medications were loaded. However, the scroll bar in the bottom left corner read “50 loaded” until the user scrolled down to the bottom of the list. This could easily confuse or mislead someone who did not know (or bother) to scroll all the way down.

**Variation in how brand and generic names are displayed**

Our work revealed that even at the same site, or on the same screen, drugs may be displayed in different ways (e.g., brand vs. generic) in different systems (e.g., inpatient vs. outpatient), depending on the type of list or task functionality. This inconsistency can confuse prescribers, especially if they are not familiar with both the brand and generic names of drugs for searching and selecting drugs.

**Organization and display of medication lists**

The adjacency and juxtaposition of drugs in a prescribing list can be a source of wrong-drug errors. One noteworthy finding is that more serious adjacency errors can arise as a result of using a “favorites” or a more limited drug pick list, which may place dissimilar drugs next to each other.

### 3. COMPOSING OR ENTERING DRUG REGIMEN/SIG

#### **Inability to order desired dose form or strength**

When prescribers cannot enter their desired dose form or strength, they may become frustrated and use free text or other workarounds, which increases error risk and which does not trigger clinical decision support.

#### **Inappropriate doses in CPOE**

Systems facilitate errors when users expect to be warned against inappropriate doses but such warnings do not fire, or worse, when orders include inappropriate doses in structured fields for the user to easily choose.

#### **Free-text fields and special instructions**

A key challenge in many systems is the use of free-text fields, as most do not engage CDS. Users often did not understand what information to enter or to what destination data in comments fields would be transmitted (if transmitted at all). Prescribers may also enter comments that contradict the sig.

## CLINICAL DECISION SUPPORT (CDS): VARIATIONS, INCONSISTENCY, AND PROBLEMATIC DESIGN

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CDS is considered by many to be the most powerful error-prevention feature in CPOE, with great hope placed in the power of simple alerts and warnings.<sup>2</sup> A decade of experience has shown that to be effective, alerts need to be much more selective, carefully designed, and ideally customized to the individual patient characteristics and context.<sup>3,4</sup> We found highly variable use of CDS across the 10 systems studied. Issues include failure to connect CDS to all of the ways a drug can be ordered and inconsistencies in how CDS was used to help distinguish look-alike and sound-alike drugs.

### **1. Inconsistency in Application and Alert Firing**

In some CPOE systems, CDS varies according to the user's role. Other systems offer only one "track" for all users. Alerts are tailored for the prescribers who need them help reduce alert fatigue,<sup>5</sup> but this variability may disrupt the clinical workflow and could prompt non-physicians (nurses, medical assistants, physician assistants) to find risky workarounds. Sometimes CDS may even vary depending on whether drugs are being ordered by brand or generic name. Other problematic issues include variability in allergy recording (entered as free text rather than being coded, true allergies vs. minor intolerances), handling fixed-dose combination medications, refills, orders from order sets, or orders from a favorites list. Alerts may fire differently depending on whether a drug is ordered from a favorites list, or from inside or outside a specialty practice.

### **2. Variable use of commercial drug data compendia vs. local customization**

Sites generally did not utilize the commercial drug compendia and their bundled CDS features "off the shelf" and instead performed many of their own modifications, requiring error prone manual efforts with each release.

### **3. Interoperability: Within organizations, sites, and systems (e.g., inpatient to outpatient)**

Interoperability between systems was repeatedly found to be a problem. Many CDS systems had inconsistencies in alerts (e.g., alert types, displays) at the same institution. For example, alert inconsistencies between inpatient and outpatient systems, can cause confusion for providers who practice in both settings.

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<sup>2</sup> Kuperman GJ, Bobb A, Payne TH, Avery AJ, Gandhi TK, Burns G, Classen DC, Bates DW. Medication-related clinical decision support in computerized provider order entry systems: a review. *J. Am. Med. Inform. Assoc.* 2007;14:29-40.

<sup>3</sup> Horsky J, Phansalkar S, Desai A, Bell D, Middleton B. Design of decision support interventions for medication prescribing. *Int J Med Informatics.* 2013;82:492-503

<sup>4</sup> Van der Sijs H. Overriding of drug safety alerts in computerized physician order entry. *J Am Med Inform Assoc.* 2006;13:138-147.

<sup>5</sup> Glassman PA, Simon B, Belperio P, Lanto A, Improving recognition of drug interactions: benefits and barriers to using automated drug alerts. *Med Care, Dec 2002; 40:1161-71*

One of the essential functions of CPOE is to generate prescriptions that can be sent and entered electronically into a pharmacy computer. While standardized transmission protocol developed by the SureScripts consortium of pharmacies and payers has improved many aspects of this communication we uncovered many continuing issues that both frustrated prescribers and pharmacists as well as posed error potential.

**1. Failure to transmit medication discontinuation orders.**

Our evaluations and interviews revealed, nearly universally, that the discontinuation of a previously ordered medication is not automatically or systematically communicated to outpatient retail pharmacies. Failure to transmit discontinuation orders creates a serious vulnerability, with patients having discontinued medications repeatedly dispensed or refilled despite being discontinued by the prescriber.<sup>6</sup>

**2. No confirmation of successful order transmission**

Patients sometimes attempt to pick up a medication from a pharmacy only to learn that the prescription was not successfully transmitted. Prescribers should receive notification when an order transmission is not successful.

**3. Difficulties in putting orders temporarily “on hold”**

Systems vary in their handling of hold orders. Some have options to suspend drugs only when patients go to the operating room. Some systems can hold orders for only a few drugs, and other systems have the “hold” function for all drugs. We saw multiple examples (e.g. failures to restart anticoagulation after being held for surgery) of related issues.

**4. Patient identification: wrong-patient errors**

Ordering a prescription for the wrong patient is a well-documented problem on paper as well as with implementation of CPOE. However, there is likely added vulnerability in CPOE because of the ease by which the wrong patient’s chart can be accessed or selected (e.g., when multiple charts are open simultaneously on the user’s screen).

**5. Medication discontinuation and reconciliation**

Medication reconciliation is an area of considerable confusion, since drugs are entered on a patient’s medication profile with two different possible meanings: 1) as a medication order which can be transmitted to the pharmacy; or (2) simply as a historical record of what has been prescribed or taken by the patient. There is widespread variation and lack of understanding in how systems and individual prescribers handle the distinction between these two types of entries, as well as in the handling of medications prescribed by other providers. Many medications discontinued are prescriptions that the patient is no longer actively taking. Thus, discontinuations are reasonable and often part of medication reconciliation, but errors can be introduced when such information is entered by non-physician staff that lack requisite clinical medication knowledge.

**6. Continuing need to have coexisting “paper” prescriptions and processes for controlled substances.**

Despite the planned implementation of electronic CPOE for opiates and other controlled drugs, for numerous reasons this promise has not been realized, creating workflow issues/inefficiencies and even adding to potential for misuse.

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<sup>6</sup> Allen AS, Sequist TD. Pharmacy Dispensing of Electronically Discontinued Medications. *Ann Intern Med*, 2012;157:700-705.

## B. PROBLEMS IN IDENTIFYING, COLLATING, LINKING, ANALYZING, SHARING AND LEARNING FROM CPOE-RELATED ERRORS

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A key finding from our study is the absence of any efficient local/institutional (or national) system for systematically gathering, analyzing, and sharing data on CPOE risks and medication errors. None of the systems we evaluated had a single centralized dedicated database for collecting and tracking and learning from CPOE safety issues. The absence of this type of centralized repository of accumulated knowledge and experience has broader negative implications for CPOE monitoring, learning, sharing, and improvement—all of which require systematic feedback to and from local and national designers and vendors, as well as transparency and oversight.

Therefore, it was necessary for us to creatively tap into a variety of often siloed information sources at each institution. In addition to collecting and cataloguing the *types of errors* we uncovered, we devoted considerable effort to identifying and describing various potential *sources of data* on CPOE errors and problems.

Our efforts included a comprehensive in-depth review of these sources related to Brigham and Women's Hospital, generating a variety of primary and secondary data related to potential CPOE errors in the two BWH pioneering CPOE systems – the Brigham Integrated Computerized System or BICS (used in the inpatient setting) and the Longitudinal Medical Record or LMR (used in the outpatient setting). We also obtained information from the other five collaborating sites, examining any available data sources. These joint efforts were quite productive, and each site identified and shared at least one highly useful source of CPOE medication error information.

### ERROR REPORTING SYSTEMS, PRACTICES, AND CULTURE

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None of the collaborating institutions had a systematic way to identify, collect, or track issues and errors related to CPOE. Typically learning takes place only after an error, and each site has its own mechanisms for identifying and reviewing errors.

Even better-developed reporting systems such as spontaneous error reporting systems suffered from a variety of shortcomings (such as being voluntary), and were infrequently used to improve CPOE. Though user frustrations and vendor-level issues with the CPOE systems should also be systematically documented, neither is currently well captured or available for either internal (organizational, vendor) or external (FDA, researchers, public) review.

We found that the pharmacist intervention logs currently being kept across all the sites do not contain information in a structured or coded way to allow for learning from the issues being addressed, thus hindering the ability to improve CPOE systems.

### VARYING/POOR QUALITY OF ERROR REPORTS

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The quality and consistency of the reports for those errors that *are* reported varied widely. Two recurrent issues from reviewing hundreds of these reports from BWH and our collaborating sites were: a) accuracy of the safety report coding taxonomy, and b) the quality and details of the report narrative, and whether it contained sufficient information to assess the role of CPOE in facilitating the error.

### FAILURE TO DOCUMENT CPOE-RELATED ERRORS IN THE MEDICAL RECORD

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Related to failure to report many errors, we also found a lack of documentation of any mention of CPOE errors or issues in the medical record, even for cases where errors were clearly flagged in the CPOE discontinuation order.

### LACK OF CENTRALIZED COLLATING OF DISPERSED INFORMATION ON CPOE PROBLEMS AND SAFETY ISSUES

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Our review of the safety and error reports and reporting systems across the sites failed to find any centralized repository within any organization for the information collected. We learned that each site—and each area within

## EXECUTIVE SUMMARY

each site—uses different terminology and processes to review medication errors and CPOE issues, thus limiting the ability to analyze, prioritize, and address errors or potential errors (or share across sites).

### LIMITED STANDARDIZED TAXONOMIES FOR CLASSIFYING CPOE ERRORS

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Closely related to the problem of collating and cross-referencing errors and problems is the need for a standardized taxonomy to classify, describe, and track these errors. Of concern was our finding that even ad hoc approaches to a more granular understanding and categorization was not on the horizon of the collaborating sites—and most had not delved into the pool of reports sitting in their various error and other HIT databases. Our project provided a useful first look, into such CPOE-related safety data at each of the sites, generating a number of important findings related to types and patterns of CPOE errors, as well as helping catalyze the further refinement of a CPOE-errors taxonomy tool we previously developed.<sup>7</sup> This taxonomy was based on the BWH MedMarx CPOE Error taxonomy tool that was initially developed for a project funded by the National Patient Safety Foundation. A critical finding from the CPOEMS Project revision was the need for refinement in classification of “What Happened” in describing a CPOE error. The refined classification has two components: a) “what happened to the patient” and b) “what happened within the CPOE system” (D, E). Thus we revised this earlier taxonomy, and our pharmacists and team have used it to categorize the error reports we collected from our own and collaborating institutions.

### POOR MAINTENANCE, AVAILABILITY, TRANSPARENCY, AND TRACKING OF SYSTEM MODIFICATION LOGS

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As we attempted to identify and assess changes to the systems made to the CPOE systems in response to errors and problems, we found that there were no official or standardized way to document and track features and modifications made to these systems or reasons why these changes were implemented.

### DIFFICULTIES IN AND FAILURE TO MONITOR BEHAVIORS OF CDS ALERTS AND PROVIDER RESPONSES

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The number and types of alerts were highly variable, particularly for drug-drug interactions (DDI), dosing limits, drug-disease interactions, and duplicate drug alerting. None of the sites could easily generate simple reports listing the alerts in place, the conditions and frequency of their “firing,” or most importantly, how often they were overridden and reasons why (although not all alerts can be described appropriately with an override rate) as well as whether the overrides were appropriate or not.

### DIFFICULTIES IN CREATING AND USING “TEST PATIENTS”

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We noted that sites were challenged in entering fictitious “test patients” to probe issues identified locally or externally or to confirm that an issue has been resolved. The requirement to “admit” a test patient, for example, or block transmission of an outpatient test prescription flowing to the pharmacy, made it difficult to easily perform CAT tool assessment testing at the collaborating sites, and limited ability to for us and the users to better learn about the systems.

### PROPRIETARY DATA ISSUES AND VENDOR PERMISSIONS TO SHARE SCREEN SHOTS

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Most vendors were amenable to sharing screenshots to support identification of potential issues. However, the refusal of one vendor to permit sharing of screen shots that could help to elucidate system vulnerabilities with the FDA and for this report runs counter to the strong recommendations of multiple high-level HIT safety panels.<sup>8</sup> From a safety viewpoint, it is hard to justify why this should be permissible. Identifying, preventing, and learning

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<sup>7</sup> Schiff GD, Amato MG, Eguale T, Boehne JJ, Wright A, Koppel R, Rashidee AH, Elson RB, Whitney DL, Thach TT, Bates DW, Seger AC. Computerized Physician Order Entry-Related Medication Errors: Analysis of Reported Errors and Vulnerability Testing of Current Systems. *BMJ Qual & Saf.* Accepted, Dec 2014. In press.

<sup>8</sup> Health Information Technology Patient Safety Action & Surveillance Plan for Public Comment. December 21, 2012. The Office of the National Coordinator for Health Information Technology.

from errors and improving prescribing safety should be a priority that should take precedence over commercial considerations.

### C. SPECIAL CPOEMS ERROR STUDIES

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We undertook a number of original studies to better understand CPOE errors in general, as well as specific types of errors that appeared to be directly related to CPOE. We report on four of these special studies performed as part of the CPOEMS project.

#### MEDICATIONS DISCONTINUED DUE TO “ERROR (ERRONEOUS ENTRY)”

One particularly novel data source we identified at BWH was a previously untapped database containing >20,000 CPOE orders discontinued annually with the reason for discontinuation being given by the clinician by as “Error (erroneous entry).” Because of the FDA’s interest in drug name issues, we focused on a series of “drug pairs” for which “Error (erroneous entry)” was indicated as the reason for discontinuation, looking for instances where the discontinuation order was followed shortly thereafter by an order for a new drug or product with a similar name, suggesting that the drug name may have caused confusion in the original order. We also retrospectively reviewed patient charts for these cases. However, clinicians almost never documented the error or its reason in the medical record. This led our team to design and implement a prospective study in which we asked physicians entering these “erroneous-discontinuation” orders to provide us the reason and additional details. We queried the physician by email within 24 hours of the order to solicit these additional details.

In this prospective study, the top categories of responses to “What happened to the patient?” were: wrong patient received drug or nearly received drug, patient received or nearly received wrong drug, and patient received or nearly received a duplicate drug (same exact drug, or in same therapeutic class). The top categories of “What happened in CPOE” include: medication ordered for wrong patient, ordered wrong drug, and duplicate order of the exact same drug.

#### REVIEW OF “VOIDED” ORDERS

We also studied “Voided” orders at one of the collaborating sites. The review of these orders, which required the physician to also check a structured reason from a menu, had not previously been undertaken and revealed useful insights. “Duplicate order” was the most frequent reason given, followed by “wrong patient” and “order on wrong encounter”.

#### ANALYSIS AND CLASSIFICATION OF PATIENT SAFETY REPORTS TO UNCOVER CPOE RELATED ERRORS AND ISSUES

A more traditional but useful data source was patient safety reports that had been coded as medication related. We were particularly interested in reports of errors that occurred in the ordering and prescribing phase (which a couple of the systems had as a category). We assessed whether these errors may have been CPOE-related, classifying whether CPOE may have been directly related to causing the error, or, even if it did not cause the error, whether better-designed CPOE systems might help prevent these errors. Although each of the collaborating organizations had formal safety reporting programs, none had previously undertaken this type of in-depth and broad review focusing on CPOE error, similar to our findings in other areas of reporting. We were able to review more than a thousand such reports using the revised BWH MedMarx taxonomy (Appendix C).

Overall, more than one third of the medication-related error reports from the ordering and prescribing phase reviewed were related to CPOE issues, and most of these represented cases where better CPOE could have prevented the error, suggesting a need for thoughtful attention to improved CPOE and particularly CDS design. The majority of CPOE-related errors were related to dose (i.e., ordered wrong dose or strength).

## DUPLICATE BRAND/GENERIC DRUG ORDERING

We extracted medication prescribing information when the brand and generic forms of the same drug appeared simultaneously on a patient's active medication list at BWH from 2011-2013. This practice of prescribing two orders of the same drug is a clue that this function should be better designed. We recommend that there be a consistent way to group drugs so the brand and generic entries of the same drug appear adjacently in CPOE. We found that orders prescribed for a few days would often stay on a patient's active medication list for years. We also observed that prescribers often ordered two prescriptions of the same medication to add doses when they sought to prescribe a dose not present in CPOE. Other prescribers entered duplicate medication orders because they wanted their patients to receive different doses on different days and did not understand this CPOE functionality. Many duplicate drug orders were reviewed, but seldom was the patient taking an improper duplicate order. It was unclear why the prescriber often wrote one order for the brand drug and another order for the generic drug.

## RECOMMENDATIONS

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In the context of the rapid growth of CPOE medication prescribing in both the inpatient and outpatient settings, fueled in part by government subsidies, greater attention to addressing the problems we identified is warranted. The CPOEMS team was not charged with more rigorously testing the impact or generating definitive evidence about the optimal solution to these problems. Nonetheless, we modestly offer the following recommendations and directions that should be considered by stakeholders with an interest in safer prescribing. These stakeholders include hospitals and other health care delivery organizations, EMR vendors, clinicians and pharmacists, payers and pharmacy benefit management, regulators, as well as the patients whose future safety depends on building a more reliable, user friendly, and consistent CPOE environment, tools, and workflow.

**TABLE 1. RECOMMENDATIONS**

### 1. GENERAL RECOMMENDATIONS

General Issues	Recommendation
Lack of consistency in display of drugs, drug names, and screen features and workflow within and between systems.	Create CPOE systems with more consistent drug name displays across systems/sites (system user interoperability)
Lack of ease and accuracy for finding desired and appropriate drug and regimen	<p>Better attention to search tools usability emphasizing user center design, consistency with other familiar search tools/functions.</p> <p>Incorporate problem/indication-based CPOE design to quickly take prescribers to drug (and regimen) of choice. Other context specific defaults (e.g., age, renal, formulary adjustment).</p> <p>Smarter and nationally standardized approaches to brand vs. generic name searching.</p>
Interoperability and communication issues between CPOE systems and pharmacies, especially medication discontinuations, directing prescriptions to desired pharmacy, and adherence data	Design systems to more reliably communicate between pharmacies and EHRs via enhanced Surescripts functionality (e.g., two-way communication related to discontinuation, adherence, indication, errors), EMR usability.
Problems and issues with "Comments" free text fields	Adopt standards for the structure, use, and

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directions and sigs	accessibility of free-text fields. Data mine free text comments fields to analyze patterns of CPOE shortcomings, physician confusion, needs for additional structured communication.
Variability and large scale ignoring/over-riding/over-firing of CDS alerts	Implement a more effective/proactive surveillance system that makes readily available granular (with physicians, units, alert types and contexts) information on alert responses
Potentials for wrong patient, wrong drug errors	Test variety of approaches including visual affordances (patient photo), work flow forcing functions (limit number of charts open simultaneously), patient and pharmacy error checks (e.g., indication)

## 2. SPECIFIC RECOMMENDATIONS TO IMPROVE CPOE SYSTEM DESIGN/FUNCTIONALITY

Issue	Recommendation
Unintuitive and inconsistent screens/functions; confusing and frustrating displays and work flows	Design more intuitive, flexible, useful search functions, with results better organized, filtered, and prioritized. Real time user support with enhanced feedback loops to developers about frustrations and non-intuitive features.
Confusing, inconsistent display of drug names	Standardize display, including drug names as well as suffixes and modifiers
Searches that often return overwhelming numbers of results and products, as well non-drug (lab, radiology) orders	Smarter defaults, context sensitive filtering
Potential for look-alike/sound-alike drug errors drug selection errors.	Build indications into search and ordering process
	Incorporate safeguards to prevent wrong-patient errors

## 3. RECOMMENDATIONS TO IMPROVE CONSISTENCY/RELIABILITY OF CDS

Issue	Recommendation
User frustration with cumbersome CDS; users resorting to large scale over-riding/ignoring of alerts and workarounds that are unmonitored for safety precautions	Better integrate CDS into workflow (see "Five Rights" <sup>9</sup> and "Ten Commandments" <sup>10</sup> ). Enhanced listening to end users. Minimize number of alerts; more thoroughly vet and test functioning and value before implementing.
Despite most common user response to alerts being to override, further useful information about override instances and behaviors not adequately captured or studied	Track and analyze overrides for alert type, rates, reasons, drugs involved, appropriateness, user demographics, and geographic unit. Standardize and create better operational definitions

<sup>9</sup> Campbell R. The Five Rights of Clinical Decision Support: CDS Tools Helpful for Meeting Meaningful Use." *Journal of AHIMA*. 2013; 10:42-47.

<sup>10</sup> Bates DW, Kuperman GJ, Wang S, Gandhi T, Kittler A, Volk L, Spurr C, Khorasani R, Tanasijevic M, Middleton B. Ten Commandments for Effective Clinical Decision Support: Making the Practice of Evidence-based Medicine a Reality. *JAMIA*. 2003;10:523-530.

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	regarding user responses ("Accept," "Cancel" etc.).
Alerts may fire inconsistently depending on user, type of list, first order/refill, etc.	Establish automated proactive surveillance to monitor alert behavior
Users come to depend on decision support safety nets that may, without their awareness, be absent (different system, bugs or changes in their usual system)	
User frustration and "alert fatigue" do not allow the realization of full safety potential of appropriate and/or critical alerts	Ensure continuous refinement of alerts
Alerts not sufficiently specific to particular individual patient or care context	Offer patient-specific drug and dosing suggestions

**4. RECOMMENDATIONS TO IMPROVE SYSTEMS FOR IDENTIFYING, UNDERSTANDING, TRACKING, AND LEARNING FROM CPOE ERRORS/PROBLEMS**

<b>Issue</b>	<b>Recommendation</b>
Errors escape systemic notice/correction	Create enhanced local reporting systems to produce an environment that systematically collects and brings together CPOE-related errors and opportunities for improvement from multiple sources. Enhanced feedback from pharmacies and patients.
Detected errors that are not investigated or may remain unexplained	Investigate reports thoroughly to understand root causes. Patient Safety Organization peer review protections to enable candid investigation of errors causing both harm and near misses. Ensure corrective action.
"Near misses," workarounds, and ad hoc corrections are often not noted, documented, studied, and escape system notice	Install proactive surveillance systems to monitor various markers of potential errors. Perform vulnerability stress tests for errors identified locally and nationally.
Errors detected and corrected by pharmacists (and the resulting inefficiencies and frustrations for pharmacists) seldom feed back for improving CPOE systems/prescribing	Re-engineer pharmacy intervention logs to ensure capture of CPOE shortcomings rather than just productivity tallies, along with dedicated organization resources to follow-up on patterns of problems identified
Error patterns are not discerned, nor prioritized for correction	Collate, organize, code, and standardize error data in a central repository
Users who do report errors left to wonder whether any action was taken, hence are discouraged from engagement in future reporting	"Close the loop" by giving feedback to users who submit reports to encourage and empower them to continue to do so in the future

**5. RECOMMENDATIONS TO ENHANCE LEARNING SYSTEMS**

Issue	Recommendation
User workarounds mask and limit understanding of systems and non-intuitive design	Provide CPOE users with real-time support, and learn from user frustrations/experience
	Improve two-way communication with/learning from pharmacies, especially including medication discontinuation orders
Multiple sites encounter similar problems but often left to solve them on their own without systematic sharing of problems and solutions	Share errors among institutions to promote corrective action
Vendors' invoking of proprietary rights inhibiting the sharing of screenshots and problems, created barrier to collaborative learning	Require vendors to permit sharing screenshots and error reports
System vulnerabilities often receive attention only after occurrence of dangerous errors or adverse medication harms	Implement systems for ongoing system testing and monitoring, such as anomaly detection systems, to spot system malfunctions proactively.

## BACKGROUND

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As part of its mission to help oversee medication quality and safety, the United States Food and Drug Administration (FDA) initiates studies to investigate and assess safety risks. The agency then uses the information gleaned to regulate pharmaceutical products and protect the public's health. The FDA has a longstanding broad interest in the ways drugs are ordered and how improvements regarding drug names, drug ordering and dispensing, and professional-patient communication can lead to safer medication use. The Institute of Medicine identified medication errors as the most common type of error in healthcare and account for approximately 7,000 deaths annually.<sup>11</sup> Although there are many different causes of medication errors, published research has estimated that 11.4% of these errors are directly related to mix-ups with drug names, including illegible prescriptions, confusing expressions of dosage forms, and misunderstood abbreviations.<sup>12</sup>

Historically, medications were ordered via handwritten paper prescriptions or verbally (e.g., via calls from a physician to the pharmacy). With the increasing adoption of electronic prescribing—called computerized prescriber order entry (CPOE) in healthcare settings—the majority of medications in the United States are now ordered electronically initially using homegrown and now largely commercial CPOE systems.<sup>13</sup> These CPOE systems direct the selection, display, storage of drug histories, as well as electronic transmission of drug orders to dispensing pharmacists and pharmacies. This new paradigm creates multiple opportunities for protections that enhance patient safety (e.g., allergy or renal dosing alerts) but also introduces the potential for numerous new types of both predictable and unforeseen prescribing and dispensing errors.<sup>14</sup> Inflexible ordering screens, inability of information systems to communicate, and prescribers relying on often inaccurate CPOE dose displays are examples of ways that CPOE systems can facilitate medication errors.<sup>15</sup> The FDA has funded this task order, creating an unprecedented opportunity to examine the characteristics of CPOE systems and to explore the potential for errors in prescribing, transcribing, and dispensing, particularly as these relate to drug names and visual interfaces.

The Brigham and Women's Hospital (BWH) Center for Patient Safety Research and Practice, in concert with the FDA and co-investigators at five remote sites, has completed the key requirements specified in this two-year FDA Task Order. This White Paper reports on the findings of the BWH FDA Computerized Prescriber Order Entry Medication Safety (CPOEMS) Project, which assembled a team of clinicians and investigators experienced in health information technology (HIT) safety. This team developed the requisite infrastructure and tools to collect and analyze data to accomplish the key aims of this task order:

**Task 1 - *CPOE Descriptions and Modifications*** centered on the description and investigation of 18 elements of interest to the FDA, which were collected using a specially designed data collection instrument developed by the Brigham team—the CPOEMS Assessment Tool (CAT) (Appendix B)—to identify issues in CPOE ordering, display, and workflow.

**Task 2 - *Identification of Medication Errors*** focused on errors potentially associated with product names and CPOE systems vulnerability. Building on Task 1 findings and multiple methods for identifying errors at the participating CPOEMS sites, we collected and analyzed CPOE-related medication errors and identified opportunities for improvement. This phase of the project centered around collection and analysis of CPOE-related medication safety data reports from the six CPOEMS collaborating centers, and a number of special studies undertaken on the BWH inpatient and outpatient systems.

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<sup>11</sup> Institute of Medicine. To err is human: building a safer health system. Washington, DC: National Academy Press; 1999.

<sup>12</sup> Lesar et al. Factors Related to Errors in Medication Prescribing. *JAMA*. Jan 1997;277:312-317.

<sup>13</sup> Hsiao C, Jha A, King J, Patel V, Furukawa M, Mostashari F. Office-Based Physicians are Responding To Incentives and Assistance By Adopting And Using Electronic Health Records. *Health Affairs*. 2003; 32, No. 8.

<sup>14</sup> Boehne J, Seger A., Amato M., Whitney D, Schiff G. Analysis of USP MEDMARX Medication Error Data: CPOE as Contributing Factor. Presented July 13, 2011 NCCMERF Meeting.

<sup>15</sup> Koppel,R., Metlay, J.P., Cohen, A., Abaluck, B., Localio, A.R., Kimmel, S.E., Strom, B.L. Role of Computerized Physician Order Entry Systems in Facilitating Medication Errors. *JAMA*. 2005;293:1197-1203.

## BACKGROUND

Task 3 - *Summary of Methods and Findings* includes this White Paper, a formal presentation to the FDA in November 2014, and additional dissemination via presentations and publications planned by the CPOEMS team at scientific meetings and in peer-reviewed literature.

The CPOEMS Project assessment of ten systems across six healthcare organizations elucidated myriad noteworthy issues relating to CPOE system design, implementation, visual designs, and patterns of use. Some of the findings and issues were familiar (although nonetheless important and warranting continuity attention), while others were more unexpected. The latter underscore the need for ongoing systematic evaluation of the CPOE systems. We conducted our observations in consultation with the FDA project staff in an iterative way, allowing specific elements of interest to the FDA to be underscored and discussed, particularly related to drug name displays and features of the various CPOE systems.

## PROJECT OVERVIEW

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This White Paper was prepared by a team of investigators based at the Brigham and Women’s Hospital Center for Patients Safety Research and Practice in response to an FDA task order aimed at better understanding and improving the safety of electronic ordering of medications. The FDA was particularly interested in drug name and display issues as well as broader safety issues in computerized prescribing systems. The two-year project consisted of two tasks outlined by the FDA. Task 1 was a detailed assessment of the characteristics of selected CPOE systems. Task 2 focused on identifying errors related to the use of CPOE systems, looking for ways errors could be identified, and understanding the types of errors and why they are occurring. The Brigham-based CPOEMS team was charged with the task of describing the variability across CPOE systems in terms of the patterns of errors with a focus on issues related to drug product names.

In Year 1 of this project we assessed ten CPOE systems across six U.S. healthcare organizations. To understand CPOE systems broadly, we selected a mix of commercial and home-grown systems to examine, as well as systems in the inpatient and outpatient settings. Because the sites in this study were chosen as a convenience sample of institutions using the leading vendor systems, this white paper makes no claims regarding representativeness of our sample.

**TABLE 2. HEALTHCARE ORGANIZATION SITES AND CPOE SYSTEMS EVALUATED**

Site	Site Coordinator(s)	Inpatient System	Outpatient System
Brigham and Women’s Hospital	Gordon Schiff, MD Adam Wright, PhD	Brigham Integrated Computing System (BICS)	Longitudinal Medical Record (LMR) LMR version 9.3.2
Harvard Vanguard Medical Associates	Thomas Sequist, MD Beverly Loudin, MD, MPH	[not applicable; only outpatient practices]	Epic EpicCare Ambulatory 2010 Release
Kaiser Permanente, Northwest	David Smith, RPh, MHA, PhD Sunshine Somers, RPh, MS	Epic EpicCare Inpatient	Epic EpicCare Ambulatory Hyperspace 2012
Montefiore Medical Center	Jason Adelman, MD, MS	General Electric (GE) Centricity Enterprise Carecast CE version 6.6.3	GE Centricity Physician Office Centricity EMR (CEMR) CEMR version 9.5
University of Illinois Hospital and Health Sciences System	William Galanter, MD, PhD Bruce Lambert, PhD (Independent Consultant)	Cerner Millennium PowerChart, Firstnet & SurgiNet V2012.01.05	Cerner Millennium PowerChart V2012.01.05
University of Pennsylvania Health System	Ross Koppel, PhD John McGreevey, MD	Allscripts Sunrise Clinical Manager V5.1	

## PROJECT OVERVIEW

We gathered data on these CPOE systems in 18 areas of interest to the FDA:

**TABLE 3. EIGHTEEN ELEMENTS OF INTEREST TO THE FDA**

1. Commercial vs. homegrown	10. How combination-product names are listed
2. Modifications and reasons	11. How drug names with modifiers are listed
3. Age of system	12. Presence and behavior of auto-complete for drug names and sigs
4. Features tailored to individual users/groups	13. Short-code capability
5. Additional features for specialty clinics/units	14. How spaces are indicated on the screen
6. How drug names are listed in system database	15. How practitioners navigate (mouse, touch screen, etc.)
7. Character number limits	16. Common alerts used
8. Fonts	17. Handling of verbal orders
9. Drug names listed as brand/generic	18. Use of drop-down menus

In Year 2 of the project, we developed a multifaceted approach to identify sources of information that could be screened to uncover CPOE-related errors. We then undertook identification and analysis of this data to find issues that pose potential risks of medication errors related to CPOE features and design. We identified and tested error-prone features and functionalities. Finally, based on these findings we present recommendations, suggesting ways to address some of the issues we uncovered and create safer systems for identifying and learning from CPOE-related medication patient safety problems.

## METHODS

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The infrastructure for this project consisted of a team of BWH lead investigators and administrative support staff along with a lead investigator (site coordinator) at each of the five collaborating sites. The BWH team coordinated project activities via weekly, bimonthly, and monthly conference calls via web conference with the site collaborators and the FDA. After obtaining Institutional Review Board (IRB) permissions for each site, screenshot permissions were requested from each of the sites and their respective vendors.\* Extensive communication was required to review their systems, uncover sources of data about CPOE system changes, and identify and interview the most knowledgeable and key IT and pharmacy specialists at each site.

To help standardize the assessments, the team developed a novel tool—the CPOEMS Assessment Tool (CAT) (Appendix B)—which incorporated specific medication-ordering scenarios to capture screen display features and functions related to the 18 elements of interest to the FDA. The tool was iteratively developed and piloted on the BWH outpatient and inpatient systems with feedback from FDA staff and site coordinators. Test-patient criteria were also developed to help standardize the system assessments.

In Task 1, we carried out a systematic evaluation of the 10 CPOE systems at the six sites via a seven-step process:

1. Held initial phone conference calls with each site coordinator to understand their CPOE implementation and plan data collection about their systems.
2. Hosted web conference sessions that allowed for remote viewing and recording of the CPOE systems. These were conducted with site coordinators and other local staff, who guided the BWH team through each CPOE system as outlined by the CAT. Customized test-patients were created and used at each site.
3. Conducted a remote session (and in some cases, onsite subsequent sessions) with a “regular user” (a clinician with basic knowledge of the CPOE system(s) and who used it on a day-to-day basis) to learn how those who use the system(s) in their everyday clinical activities understand and interact with the system(s).
4. Two BWH investigators conducted site visits at each organization to interview key CPOE-related leaders to follow up on questions raised in the remote sessions and to further examine, evaluate, and understand the functioning of their CPOE system(s).
5. Transcribed extensive field notes and digital recordings from the site visits and organized the screenshots to summarize findings related to the functionality of the systems studied. Transcripts were analyzed to identify key themes.
6. Reviewed data collected to identify any missing elements from the standardized assessment and held individual conference calls with each site coordinator to obtain additional data when necessary.
7. Organized and synthesized information about the 18 elements of interest and other findings across the ten CPOE systems to produce the findings and noteworthy issues presented in the Task 1 report.

To collect information on CPOE system modifications made in response to the potential for medication error, we:

1. Requested, collected, and assessed data sources containing information on modifications to the CPOE systems and why these changes were made. Although many of these sources were less than fruitful, some revealed important changes designed to prevent future medication errors.

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\*Epic would not grant permission to share requested screenshots

## METHODS

2. Conducted in-depth reviews of sources available for the BWH's inpatient and outpatient systems to determine which would have the most useful information regarding CPOE system changes associated with the potential for medication error.
3. Requested from the site coordinators the five to ten changes to their system(s) they considered the most critical in addressing potential medication error concerns.

In Task 2, we investigated potential CPOE-related errors in more detail by identifying potential data sources at each site, which were then screened by the local investigators for their potential usefulness for uncovering CPOE-related problems. Any of these found to be potentially useful de-identified and shared and reviewed by a BWH team of clinicians, pharmacists, and informatics experts. A comprehensive investigation including collection of new primary data was also undertaken at BWH. Other available data from collaborating sites were also collected and analyzed.

- a. Safety and adverse event reports
- b. Alert override, acceptance, and firing rates
- c. Pharmacy and pharmacists' intervention logs
- d. Health Information Technology (HIT) feedback and redesign reports
- e. Clinical decision support (CDS) inventory
- f. Institutional safety newsletters
- g. Medication safety committee meeting minutes
- h. Institutional root-cause analyses
- i. Special studies:
  - i. Medications discontinued with reason given as "Error (Erroneous Entry)" (at BWH)
  - ii. Duplicate active brand-generic medications data (at BWH)
  - iii. Voided orders (at another site)

Following requisite IRB and other approvals, these data were obtained and then reviewed in two phases: (1) by research assistants and pharmacists and then (2) by the full CPOEMS team. The BWH MedMarx Taxonomy (Appendix C) from a previous study was deployed and further refined to describe and classify the types of errors found. The data were then summarized and synthesized to describe major trends in types of medication-related CPOE errors across the sites.

We incorporated data from CPOE system evaluations and interviews conducted during the Task 1 activities that used the CAT (Appendix B) to test and directly observe features, functionalities, and other characteristics that could contribute to medication errors. Idiosyncratic system characteristics and behavior were identified throughout the project, and finally, a functionality test using test cases was designed to further investigate whether a functionality issue was unique to certain systems, or seen across sites (Appendix E).

## CPOE SAFETY - FINDINGS AND ISSUES

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Our analysis of these current CPOE systems revealed a high degree of variability in multiple features, both within and across systems and sites: search and display of medications, selecting and ordering medications, composing regimen sigs, and the extent and type of clinical decision support to guide the prescriber. In collecting information and studying the types of CPOE errors that occur at each site, we also found a great deal of variability in the way that this information is collated, stored, used, and shared.

### A. CPOE SEARCH, DISPLAY, ORDERING, AND WORKFLOW

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Throughout our research we found general variations in CPOE displays, functionality, and workflows. This variation occurred at every level: between sites, within sites (e.g., differences between inpatient and outpatient CPOE at a particular hospital), and within single systems (e.g., differences between ordering two different drugs in the same system). Given that prescribers are often working on multiple CPOE systems, and trainees can experience a dozen or more systems as they rotate through various hospitals and clinics, inconsistent system design or insufficient prescriber training and support may hinder accurate prescribing. In addition, lack of understanding of how a system works and/or frustration with system design that is either non-intuitive or impedes workflow may be leading to workarounds that also increase the risk of error. In addition to the negative implications for users working on multiple systems, we identified a variety of types of vulnerabilities to error with potential repercussions for patient safety. Selected examples and screens to illustrate these issues are described in this section. Because of the FDA’s interest in drug names and how they are displayed, we pay particular attention and give examples to drug name issues.

#### DRUG SEARCHING: FINDING THE DESIRED DRUG

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We found that prescribers often encountered problems and frustrations finding a medication they were trying to order. One reason is that their mental model of how drugs are searched may differ from the way the system was designed by knowledge management engineers. We found that search functionalities differed across the systems, and users were sometimes unaware of the various ways that drugs could be listed in their system(s).

For example at some sites, ordering fixed-dose combination drugs was confusing and required that the two active ingredients in fixed-dose combination drugs be entered in a particular order for searching. Forcing prescribers to know generic drug names and the specific way in which medications must be searched can create user frustration. One site listed drugs alphabetically, which made finding a drug like Bactrim (requiring a search for sulfamethoxazole) difficult. This system has a “starts with” search function and lists Bactrim as sulfamethoxazole/trimethoprim, requiring the prescriber to know how to enter the correct search string to find the correct drug. Developers created a workaround using a brand-name “alias” for Bactrim; however, when searching another fixed-dose combination drug product such as Norco, residents were unable to find or order this drug (hydrocodone/acetaminophen). They would unsuccessfully search for hydrocodone; instead the prescriber had to search for acetaminophen and then scroll through a long list to find the drug.

In this same commercial system, the user can opt to search a string of letters using the “contains” search function (Figure 1). Here, the search in their outpatient returned an often overwhelming list of all of the products containing that particular string of letters, including in the name of drugs, laboratory tests, etc.

CPOE SAFETY – FINDINGS AND ISSUES: CPOE SEARCH, DISPLAY, ORDERING, AND WORKFLOW

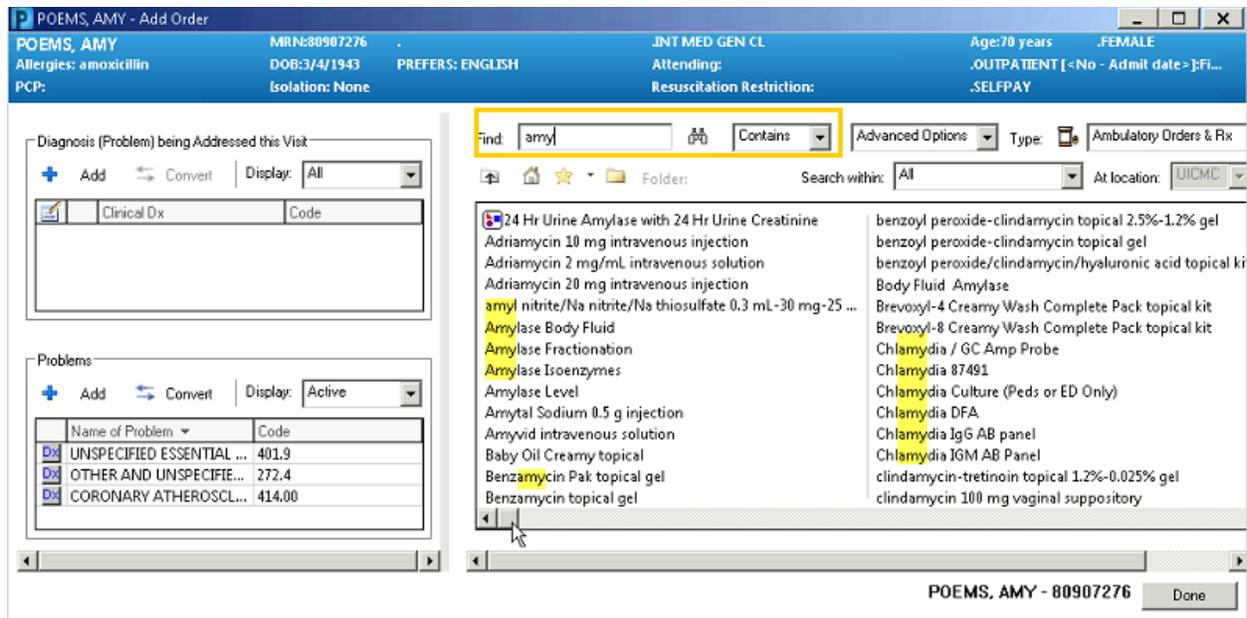


FIGURE 1. IN THIS SYSTEM, USERS CAN SEARCH FOR A DRUG BY ENTERING A SEARCH STRING AND INDICATING WHETHER THEY WOULD LIKE RESULTS TO BE FILTERED BY OPTIONS THAT START WITH THE SEARCH STRING, OR OPTIONS THAT CONTAIN THE SEARCH STRING.

We found that users of this system were often unaware of the ability to choose between “contains” and “starts with,” and may be both frustrated with not finding desired drugs while for other drugs and overwhelmed when receiving the very long results for certain drugs, such as acetaminophen. Figure 2 illustrates such an overwhelming list from a simple search for “acetaminophen (generic Tylenol).” In addition, the search results list start with combination products, making it difficult and tedious to find plain acetaminophen.

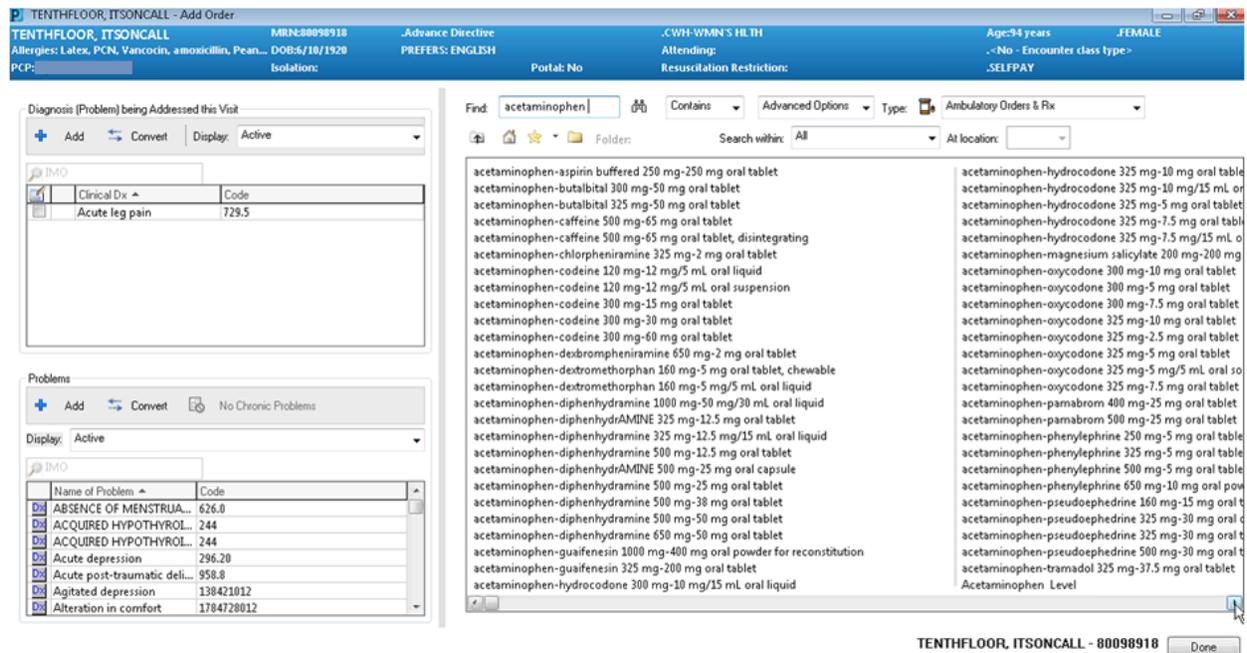
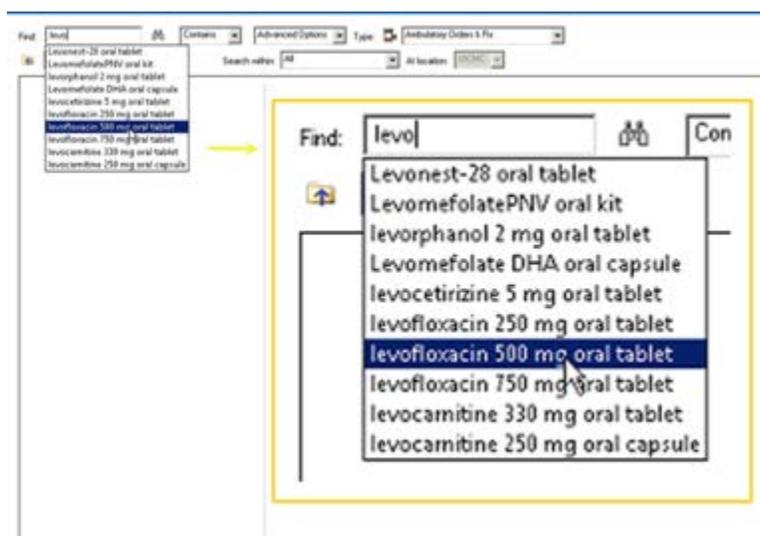


FIGURE 2. THE SEARCH FUNCTION “CONTAINS” OFTEN YIELDS MANY SEARCH RESULTS, LISTING FIXED-DOSE COMBINATION DRUG PRODUCTS FIRST.

Most systems had support for both browsing (e.g., picking a drug from a list) alphabetically and searching for a specific drug by entering a search string; however, the latter method was by far the more common paradigm.

### DRUG SEARCHING: PRESENCE AND BEHAVIOR OF “AUTO-COMPLETE” FOR DRUG NAMES AND SIGS

Auto-complete is a term used for a functionalities that try to predict what the user is typing and includes both auto-suggest and auto-fill capabilities. Auto-suggest presents users with suggestions that they may choose as they are typing in the first few letters of a drug name (similar to the familiar auto-suggest functionality in Google searches; Figure 3). Auto-fill automatically turns the first few letters of a word or an abbreviation into a full word, phrase, or drug name. We encountered unexpected results for the number of characters necessary to produce search results (as few as one letter at one site). Most systems we evaluated did not have auto-fill capability enabled for the drug name search.



**FIGURE 3. IN ONE INPATIENT SYSTEM, WHEN THE USER STARTS TO TYPE IN A MEDICATION NAME, THE SYSTEM AUTOMATICALLY SUGGESTS MEDICATIONS IN A DROP-DOWN MENU BASED ON THE CHARACTERS ENTERED.**

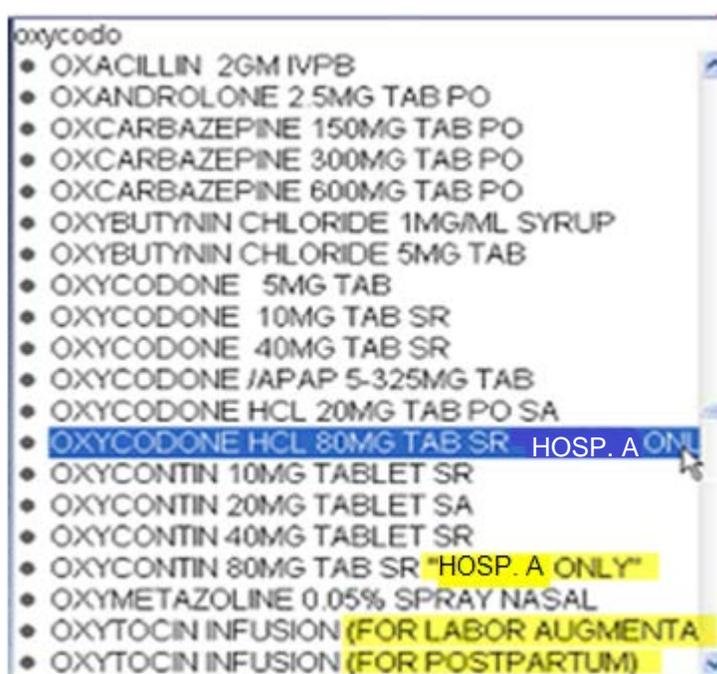
Despite their convenience, there are also dangers with auto-fill and auto-suggest. At one site, staff had worked hard for many years to optimize their drug search capability, manually setting the order in which drugs were returned to reflect the institution and the pharmacy’s best practice recommended choices. However, the turning on by the vendor of the auto-complete capability bypassed this work, and returned drug options in an unpredictable order. Pharmacy leaders at that site advocated turning off this feature due to safety concerns over selecting the wrong drug and overlooking the correct or preferred drug.

Another feature examined was whether auto-fill was enabled for other medication attributes (e.g., dose) besides the medication name. Here too there was considerable variability. Auto-fill was enabled most commonly in completing so-called “order sentences” or auto-filled sigs. The prescriber could simply edit these order sentences and modify them based on his or her preferences. Thus this capability provided an initial starting point of the order sentence and possibly improved ordering efficiency. Other auto-filling capabilities included entering dispense quantities, which was made possible due to modifications made by users at some sites using their system’s order set capability. However, such modifications were at times more difficult and resource-intensive, as they are typically built by IT pharmacists and vetted by a formulary committee. The order set feature is another way for an institution to encourage physicians to order medications based on previously agreed-upon guidelines; modifications are discouraged by making it difficult to edit the auto-filled information. The auto-fill features from knowledge vendors were felt to get in the way of the desired institutional guidelines or pathways to preferred or safest regimens. One system will over-ride that quantity that the physician manually enters, and we observed several instances where it doubled or tripled the quantity of narcotic pills that the physician had entered, leading

to prescription with an erroneously large quantity that was automatically calculated from this structured sig, rather than the physician's careful manually entered more limited quantity.

#### DRUG NAME DISPLAY ISSUES: ENCUMBERING MEDICATION FIELD NAMES WITH OTHER FEATURES OR VERBIAGE (OFTEN TO OVERCOME LIMITATIONS IN THE SYSTEM)

We found several examples of additional descriptors, often indications or other warnings, being included within the drug name field, tacked onto the medication names. Although these efforts represented an attempt to assist prescribers in selecting the correct medication, such tampering with drug names should be viewed as either a workaround necessitated due to lack of other decision support functionality for ordering (e.g., ordering by indication, see below) or as a marker for error-prone situations (with these being creative jerry-rigging efforts to decrease their potential). In one system, the name of the healthcare facility in the system where that medication was available was added to the end of the drug name (Figure 4). The CPOEMS drug name and IT experts felt that such tampering with the drug name field was a marker for needed but missing decision support and design capabilities, such as order by indication, and introduced potential for confusion or new errors.



**FIGURE 4. ONE INPATIENT SYSTEM USES A NUMBER OF MODIFIERS ADDED TO THE END OF DRUG NAMES, INCLUDING RESTRICTIONS TO PARTICULAR SITES, AS WELL AS INDICATIONS.**

#### DRUG NAME DISPLAY ISSUES: TRUNCATION OF MEDICATION NAME AND CHARACTER LIMITATIONS

Medication names are sometimes truncated due to character limits, which can vary by monitor size, screen resolution, and window size (Figure 5). If important details that might affect decision making are truncated, medication errors can result. Some systems attempt to avoid truncation by wrapping the drug name to the next line or creating a very large character limit. Systems employing truncation usually provide the full drug name when the user holds the cursor over the truncated name or adjusts the drug name column width, although this is not always obvious to the user.

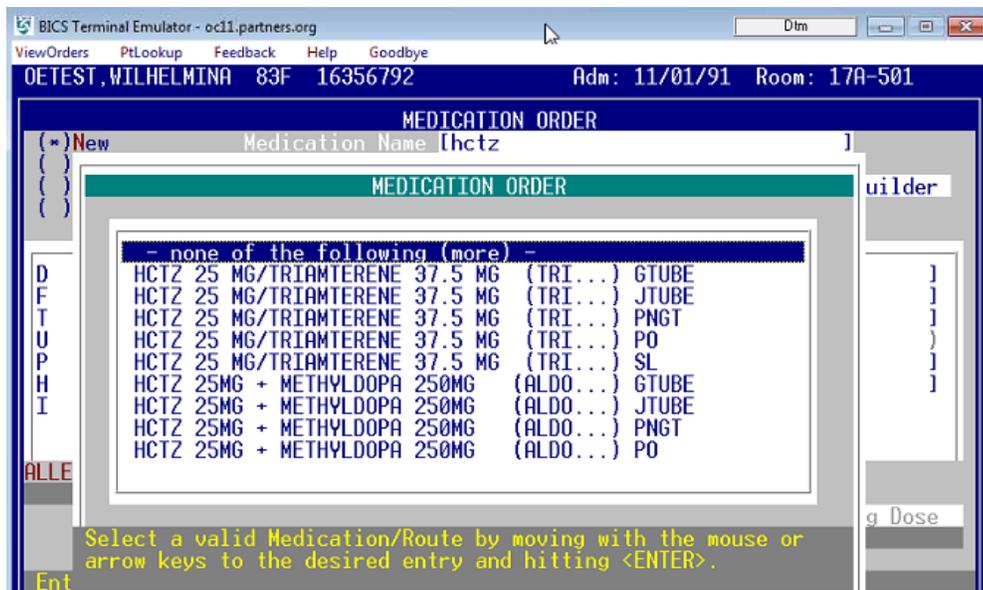


FIGURE 5. BWH INPATIENT SYSTEM TRUNCATES DRUG NAMES DUE TO A CHARACTER LIMIT. THE UNABBREVIATED NAME CAN BE SEEN ONLY AFTER THE PRESCRIBER SELECTS THE MEDICATION.

#### DRUG NAME DISPLAY ISSUES: SUFFIXES AND OTHER MODIFIERS

Across systems, drug name modifiers (e.g., double strength, single strength, extended release, sustained release, etc.) appeared primarily at the end of the drug name. A typical example is the BWH inpatient system, in which modifiers appear in abbreviated format at the end of the drug name (Figure 6).

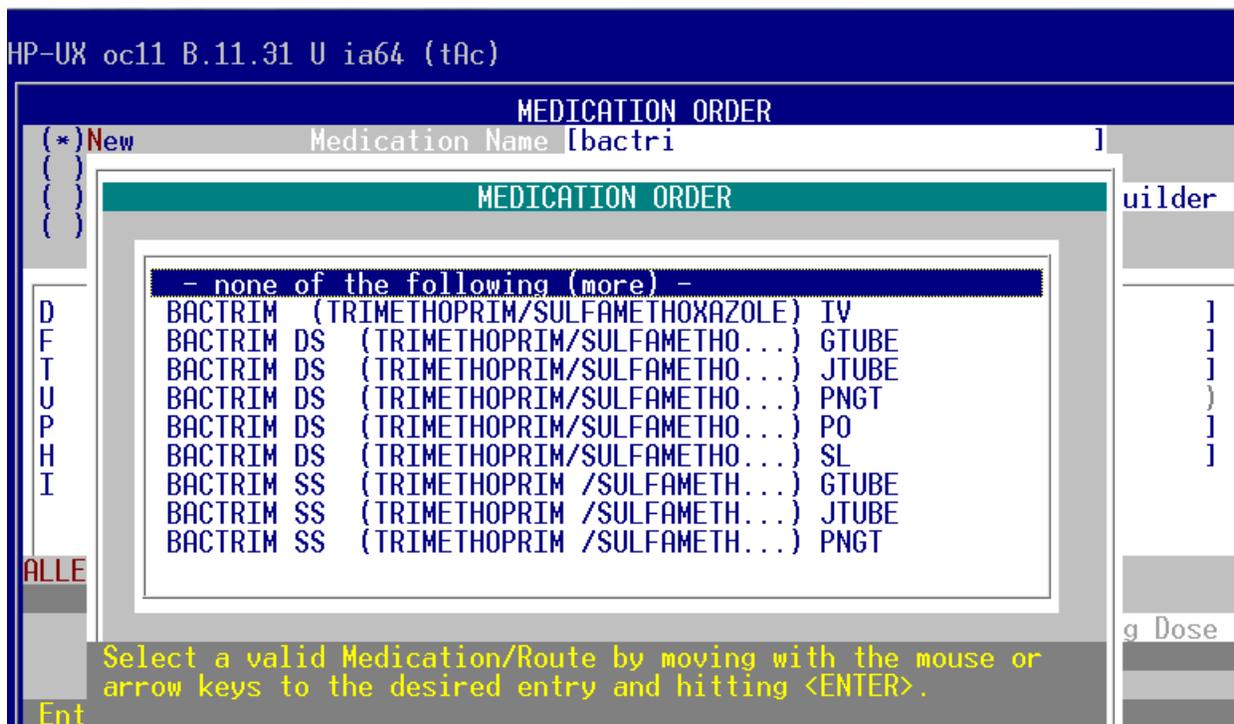
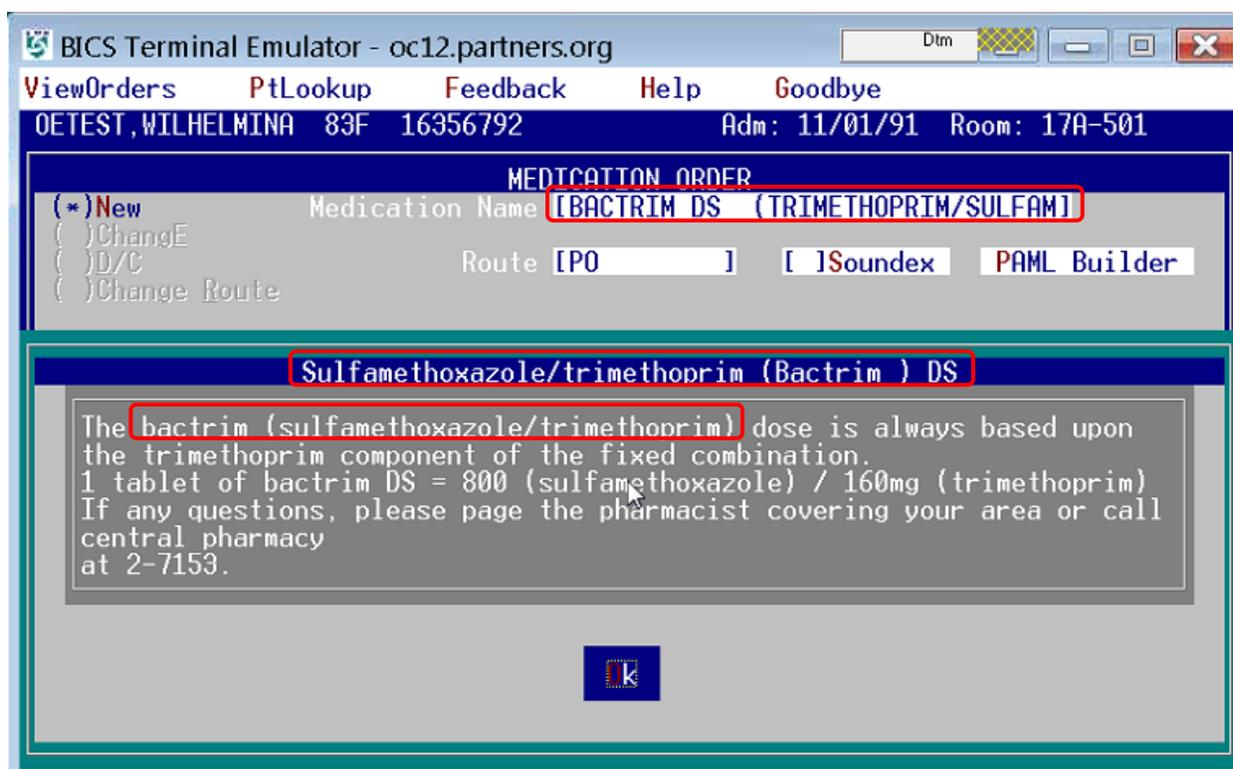


FIGURE 6. BWH INPATIENT SYSTEM WITH ABBREVIATED DRUG MODIFIERS.

This example also demonstrates another frequent finding: inconsistencies within a single system. The last three results also include a space after the name of the first combination product (trimethoprim), which the other entries inexplicably did not (Figure 6). It also appears that the results are alphabetized, with DS options listed above (before) the SS options. And when the user selects one of the choices, the full name of the drug can be seen in *three* different ways on the next screen (Figure 7).



**FIGURE 7. BWH INPATIENT SCREEN SHOWS ENTIRE DRUG NAME AFTER CLICKING ON DRUG NAME, AND THE DRUG NAME APPEARS ON THIS SCREEN IN THREE DIFFERENT WAYS.**

In another outpatient system, the drug modifiers appear in all caps after the drug name. Drug name modifiers are not truncated by the text box, but by the width of the column, which can be expanded to view the entire search string. Though the modifiers are abbreviated, it is sometimes unclear what these abbreviations indicate.

#### DRUG NAME DISPLAY ISSUES: DISPLAY OF MEDICATION CONCEPTS

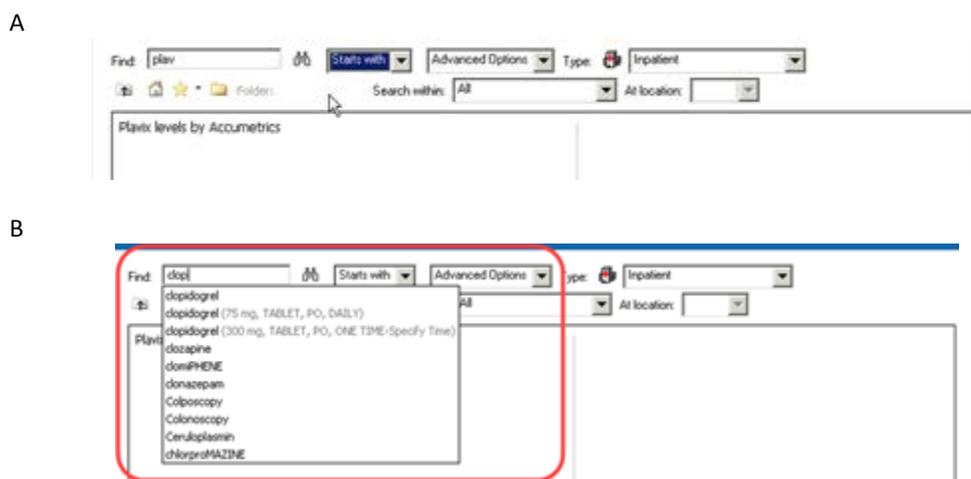
The display of medications with identical names but different medication attributes (e.g., dosage form) was observed in some systems and showed potential to introduce medication errors. In some systems the indication is added immediately next to its name: “Clonidine-ADHD” and “Clonidine-BP.” Some systems also have the medication attributes next to the drug name: “Wellbutrin SR twice daily” and “Wellbutrin XL once daily.” The display of medication concepts and attributes is intended to help prescribers to select the correct drug formulation; however, the attributes especially if they add to the length of the drug name, can get truncated, and some providers select a choice with an attribute that conflicts with the sig. For example, a prescriber might pick “Wellbutrin SR twice daily” with a sig “tk 1 po qd.” We found this problem not only in an EHR that utilized a commercial knowledge base but also in one that used a proprietary medication dictionary. An area of understanding that needs further evaluation is how to make the displayed data correspond to the user’s workflow and decision making for selecting the correct medication.

**DRUG NAME DISPLAY ISSUES: ITEMS IN DROPDOWN LISTS NOT INITIALLY VISIBLE**

In one outpatient system, modifiers appear at the end of the drug name, but the numerical ordering is inconsistent, and the highest doses available are usually listed at the top. When “ferrous sulfate” was searched, an overwhelming 191 medications were loaded. However, the scroll bar in the bottom left corner read “50 loaded” until the user scrolled down to the bottom of the list. This could easily confuse or mislead someone who did not know (or bother) to scroll all the way down.

**DRUG NAME DISPLAY ISSUES: VARIATION IN HOW BRAND AND GENERIC NAMES ARE DISPLAYED WITHIN SYSTEMS (DIFFERENT DRUG NAME DISPLAY ON DIFFERENT SCREENS)**

Our work also revealed that even at the same site, drugs may be displayed in different ways (e.g., brand vs. generic) in different systems (e.g., inpatient vs. pharmacy), depending on the types of lists or task functionality. This inconsistency could confuse prescribers, requiring that they be familiar with both the brand and generic names of drugs. Some systems more strongly encourage drug ordering by either generic or brand names. For example, a search by brand name in one outpatient system returns drugs by both brand and generic names, but in separate columns. However, another site decided to exclude all brand names from its inpatient system to promote generic prescribing (Figure 8). In the BWH outpatient setting, prescribers most frequently ordered drugs by searching for their generic names, but fixed-dose combination drug products were most often ordered by brand name, likely due to the difficulty of remembering the individual ingredients. In this system the prescription was recorded with either the brand or the generic name, depending how it was ordered by the physician. While this approach appeared to be a nice feature (thus a patient and prescriber familiar with “Lasix” rather than “furosemide” would see the brand drug appear their prescription and on the medication list), it also opened the door to duplicate errors where one doctor would prescribe Lasix, another furosemide (ignoring duplicate drug alerts) and the patient could end up with both medications on their medication list, an error documented (see Duplicate Brand and Generic Drug Ordering section).



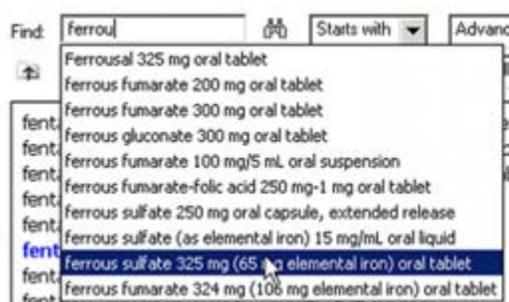
**FIGURE 8. THIS SYSTEM DOES NOT RETURN ANY RESULTS WHEN THE USER SEARCHED A BRAND NAME, PLAVIX (A), BUT DOES RETURN RESULTS WHEN THE DRUG IS ORDERED BY ITS GENERIC NAME, CLOPIDOGREL (B).**

**DRUG NAME DISPLAY ISSUES: ORGANIZATION AND DISPLAY OF MEDICATION LISTS**

The adjacency and juxtaposition of drugs in a prescribing list can be a source of wrong-drug errors. The very nature of a list creates the risk that the user will pick the wrong item – often an item adjacent to the correct item. The variety of adjacency errors include what the military would call “target acquisition errors” (the user means to click the correct item, but mistakenly clicks an adjacent one), knowledge errors (the user does not know the difference between the items and clicks the wrong one), and truncation errors (the user selects an incorrect item because important details that might have affected his or her decision are truncated).

One noteworthy finding is that adjacency errors can arise unexpectedly as a result of using order sets, “favorites,” or any limited drug pick list. Drugs that are not typically listed adjacently can appear next to each other in a shortened list. For example, nimodipine and famotidine could appear next to each other in a favorite or neurosurgical order set. This may promote a pick list error caused by adjacency or name confusion.

Some adjacency issues arose from order sentences being organized in non-intuitive ways, a problem we observed particularly at two sites (Figure 9). Alternatively, some systems displayed orders in search results that appeared identical (e.g., three identical orders in a row), but actually differed in fields such as frequency, number of tabs, etc., which could be truncated or to which prescribers had to pay special attention. The additional details are seen only by clicking on each option. In other systems, certain formulations are not adjacent to each other on the selection medication list because medications are organized by number of doses. This issue is compounded when parts of the display are truncated, preventing the ordering physician from seeing differences between the line items.



**FIGURE 9. VARIOUS IRON SALTS IN THE DROP-DOWN SEARCH OF “FERROU” IN ONE INPATIENT SYSTEM.**

#### COMPOSING OR ENTERING DRUG REGIMEN/SIG: INABILITY TO ORDER DESIRED DOSE

When prescribers cannot enter their desired dose, they can become frustrated and bypass with structured sig and use free text. This can increase error risk because it does not trigger clinical decision support (see below for more information on CDS) and can even conflict with other aspects of the order. Examples of this situation and resultant errors were found in the BWH safety reports. Investigating confusing sets of dosing instructions for patients in the BWH system, the dose field had to be filled in to proceed. However, apparently when physicians could not find the desired dose in the CPOE dose field, they had to add a conflicting order in the free text.

Systems sometimes do not allow the prescriber’s desired dose and dose units. In one of the inpatient systems we assessed, a non-standard dose of argatroban could not be ordered with the proper units (this was later fixed so that the default is the correct units; Figure 10).

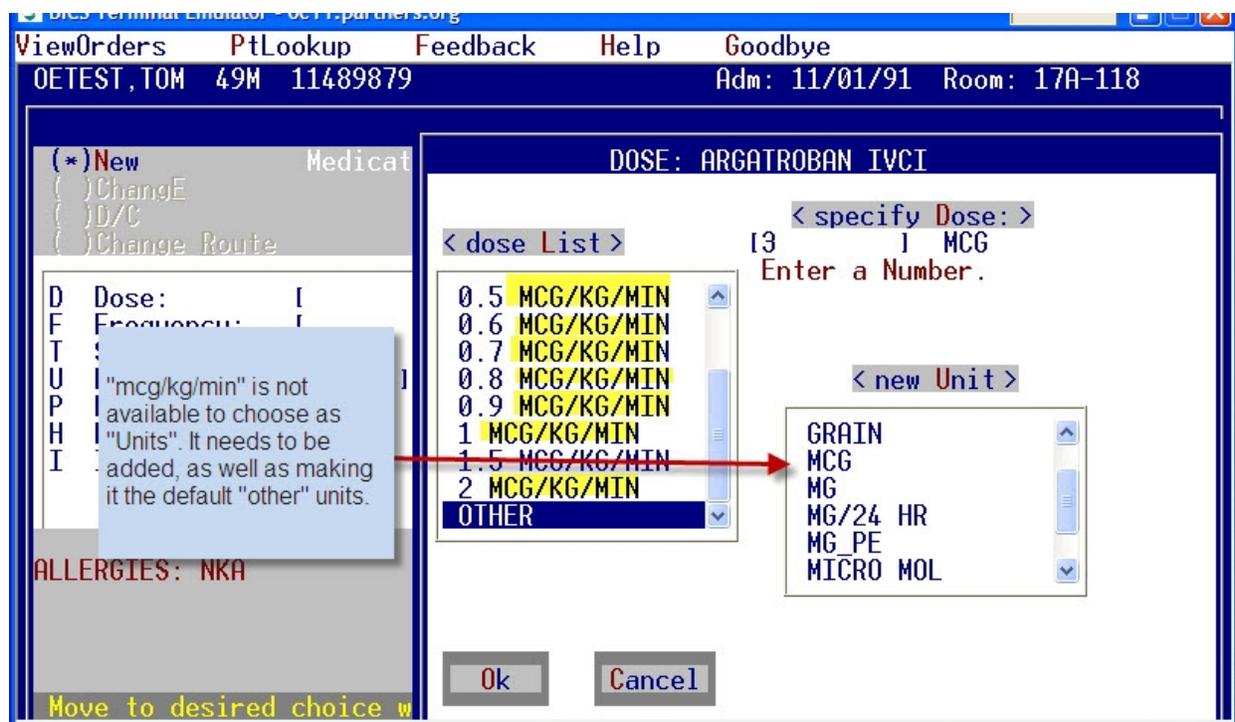
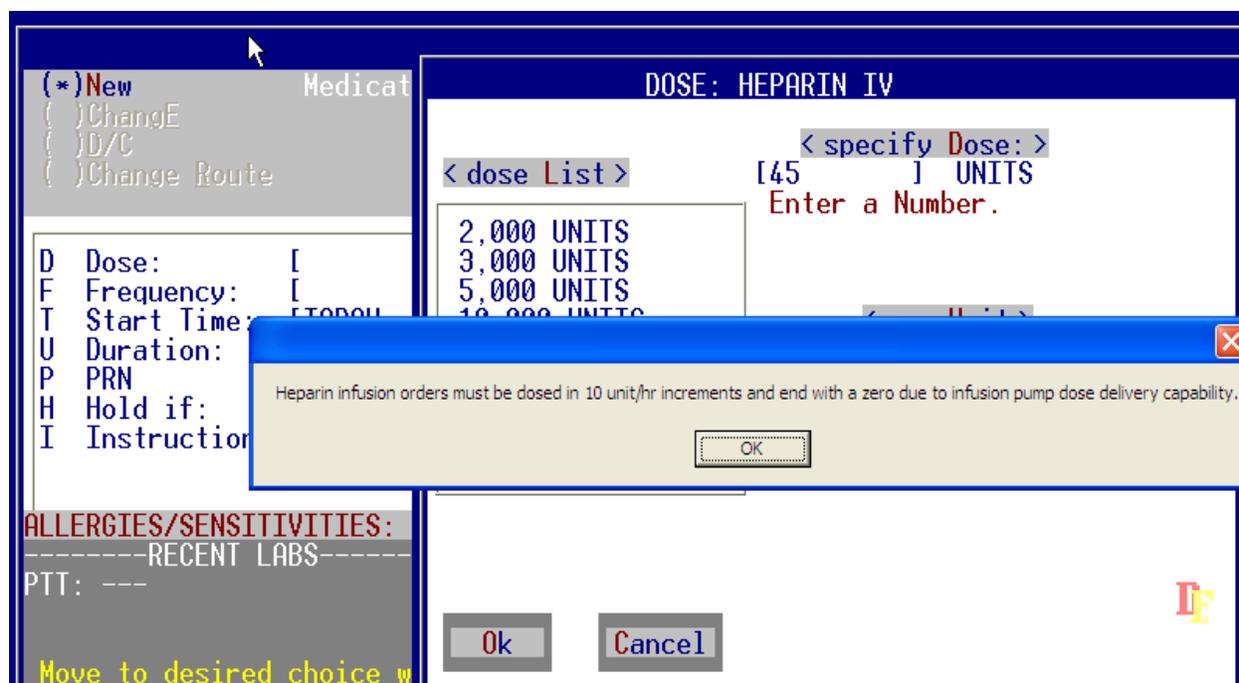


FIGURE 10. ALTHOUGH THE PROPER DOSE UNITS WERE AVAILABLE IN THE LIST OF SUGGESTED DOSES, THE PROPER DOSE UNIT WAS NOT AVAILABLE FOR SELECTION WHEN THE USER TYPED IN A NON-STANDARD DOSE OF ARGATROBAN. THUS, THE USER COULD NOT ENTER A FREE TEXT DOSE AND CHOOSE THE PROPER DOSE UNITS.

#### COMPOSING OR ENTERING DRUG REGIMEN/SIG (DOSE, TIME, AND QUANTITY): INAPPROPRIATE DOSES IN CPOE

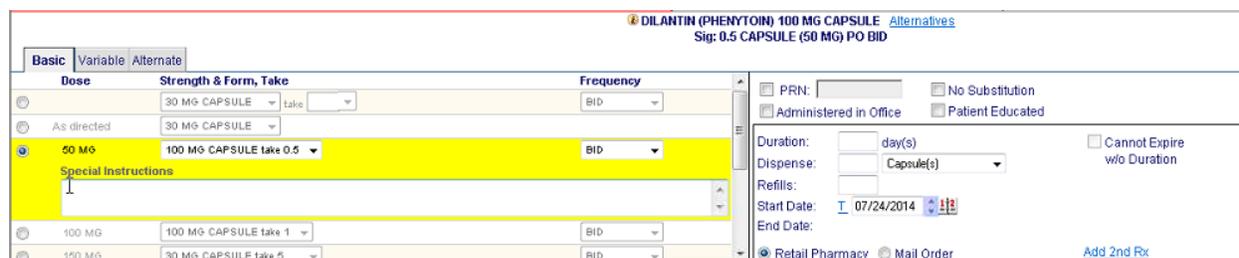
CDS often prevents or warns prescribers against ordering inappropriate doses—but not always. Some systems have maximum dosing alerts, while others lack maximum dosing alerts or have them only for particular drugs. Systems facilitate errors when users expect that the system will warn against inappropriate doses when in fact it does not, or worse, when orders include inappropriate doses in structured fields for the user to easily choose. Additionally, the CPOE system should “know” whether a patient has *not* previously been on a particular medication, and CDS should fire an alert if the prescriber orders, for example, a high dose of a long-acting medication such as fentanyl (who is opiate naive, which represents a dangerous order). Based on an adverse event, one of our sites went to great lengths in modifying their CDS to try to prevent opiate-naïve patients from inappropriately starting a high dose of this drug.

Based on specific problems encountered, IT designers and decision makers strove to improve their systems by adding limitations to prevent physicians from ordering inappropriate doses. For example, the BWH inpatient BICS OE system was modified to allow heparin doses only in units of 10. For the medication heparin route IV (the heparin drip), the dose in units/hr needed to be restricted because the infusion pumps are accurate only in 10-unit increments. A pop-up message now alerts the user to enter only values that end in zero (Figure 11).



**FIGURE 11. HEPARIN COULD PREVIOUSLY BE ORDERED IN BICS IN A DOSE THAT COULD NOT BE ACCURATELY GIVEN; BUT NOW IF A USER ENTERS AN UNADMINISTRABLE DOSE, AN ALERT DIRECTS THE USER TO ENTER A DOSE IN UNITS OF 10.**

In another example, although CPOE should never allow a half *capsule* to be ordered (as capsules cannot be accurately split), one outpatient system included a choice of prescribing a half capsule of Dilantin with a structured sig option that listed “100 mg CAPSULE take 0.5.” While most CPOE systems would allow a user to write in a half capsule as free text, having half capsules and incorrect doses in the structure field is especially dangerous. Because prescribers often come to rely on CPOE systems to tell them what is safe or acceptable to prescribe, such failures to warn, combined with prescriber lack of knowledge, can be dangerous.



**FIGURE 12. A HALF CAPSULE IS ONE OF THE AVAILABLE CHOICES IN THE STRUCTURED FIELD WHEN ORDERING DILANTIN. HALF CAPSULES SHOULD NOT BE GIVEN FOR ANY DRUG BECAUSE THEY CANNOT BE ACCURATELY SPLIT.**

We are aware of one commercial installation at a major academic center that users only free text (as opposed to structured sigs)—a situation that poses grave potential for errors. One system of the systems we studied used free text for dosing instructions, but interestingly, the free text was checked for spelling and dosing issues. For example, when the user typed “half capsule daily,” the system alerted the user “instruction was not understood” (Figure 13). While this order could still be placed, the user was aware that this was not a normal order that the CPOE system could understand and might be perplexed by such an error message. However, many of these warnings were unspecific and unhelpful to users.

FIGURE 13. SOME CPOE SYSTEMS CHECK THE FREE TEXT FOR SPELLING AND DOSING ISSUES.

### COMPOSING OR ENTERING DRUG REGIMEN/SIG: COMMENTS FIELD AND SPECIAL INSTRUCTIONS

A key challenge we observed is the use of comments fields. Users often did not understand the function of particular fields, i.e., what free text information could or should be entered, and whether and where data in comments fields are transmitted. For example, one CPOE system allows prescribers to create a structured sig but also offers two additional fields: “Special Instructions” and “Comments.” “Special Instructions” are transmitted to the pharmacy and are intended to be printed on the label, such as “do not drive while taking” or “avoid sun exposure.” However, prescribers sometimes enter comments that contradict the sig. For example, they might order a medication with frequency “once daily” and then add the comment “take two times a day on Monday, Wednesday, and Friday.” This ambiguity can lead to confusion for pharmacists (and patients), resulting in callbacks for clarifications, significant dispensing delays, and dispensing and labeling errors.

In some systems, the “Comments” field is intended for internal communications that are stored with the prescription but are *not* transmitted to the pharmacy, such as “do not refill without my authorization” or “patient is on a narcotic contract.” However, prescribers sometimes enter comments in this field that are intended for the pharmacy, not realizing that (at least in this CPOE system) they will not be transmitted at all. As explained below, both these free text fields are often used as a special type of workaround that can lead to additional errors, extra work, and frustration. To the extent that free text comments represent extra efforts on the prescriber’s part to communicate needed/desired information to the pharmacy or patient, they can be a valuable component of electronic prescribing. But such efforts are often compromised by design confusion, ambiguity of free comments instructions, or at the very least lack of standardization and clarity for the end users. Finally, some comments fields may or may not persist when a drug is renewed, creating errors such as one we documented: initial titration instructions repeated carried over to subsequent renewals of that prescription. These initial “Comments” instructions (i.e., take one then two, then three tablets) persisted even after the initial lower dosage tablet structured dosage was escalated resulting in dangerously contradictory information (leading the patient to overdose from taking too many of the higher dose form). Finally, “Comments” fields are being mandated for

controlled substances prescriptions to document the diagnosis/indication. This requirement is being increasingly enforced in an effort to prevent narcotic abuse; however it lacks a standardized approach.

### CLINICAL DECISION SUPPORT (CDS): VARIATIONS, INCONSISTENCIES, PROBLEMATIC DESIGN

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Using computers to prescribe medications offers support for higher quality clinical decisions in a variety of ways. These include suggestions for optimal medication and dosing choices, reminders and corollary orders for monitoring, and a variety of “alerts” warning prescribers of potential contraindications based on drug allergy, duplicate or interacting drugs, or lab test results. Since the beginning of electronic prescribing, CDS has been demonstrated to be a powerful error prevention feature in CPOE, with the hope that simple alerts and warnings could positively and reliably affect prescriber ordering behaviors.<sup>17</sup> We now know that such early hopes and understandings of CDS must now be tempered by a decade of experience showing that most alerts, particularly those that fire after an order has been entered, are ignored or overridden.<sup>18</sup> To be more effective decision support alerts need to be much more selective, carefully designed, and ideally customized to the individual patient characteristics and context (e.g., age, test results, prior experience with that drug, and even prescriber characteristics such as specialty [e.g., oncologist vs. PCP]).<sup>19</sup> Consideration needs to be given as to when to best use “hard stops” (which can annoy prescribers) vs. simple (more likely to be ignored) education alerts.<sup>20</sup> We found highly variable use of CDS across the 10 systems studied.

Alerts generally require a “trigger” in the system to activate the CDS alert. However, we discovered system flaws that led to orders being placed that bypass the trigger and thus precluded the firing of the alert. The surprising variety of ways to place an order for a medication suggests the need for clinicians and IT developers to work together to ensure that all workflow options trigger the necessary CDS. For example, in one of the systems we studied, alerts do not fire consistently when drugs are ordered from the physicians’ favorites list, even though they do fire when they are ordered from the regular medication search list.

Programming logic in crafting CDS alerts can be inconsistent, and both the content and visual aspects need to be improved. We noted that the well-meaning warnings for look-alike/sound-alike (LASA) drugs often do not provide enough information to assist prescribers in distinguishing between the drugs and to know which drug was for which condition or situation. For example, because the current glyburide and glipizide LASA alert in the BWH inpatient system does not clearly state the differences between the drugs (see Figure 14), the alert is not optimally helpful to the clinician who may be uncertain about the difference between these two drugs. More helpful information—presented in an organized format, with less text—would be more effective, e.g., “Glyburide: sulfonylurea with higher risk of hypoglycemia; avoid in the elderly and if CrCl < 50. Do not confuse with Glipizide: shorter acting and preferred sulfonylurea in renal insufficiency and in the elderly.”

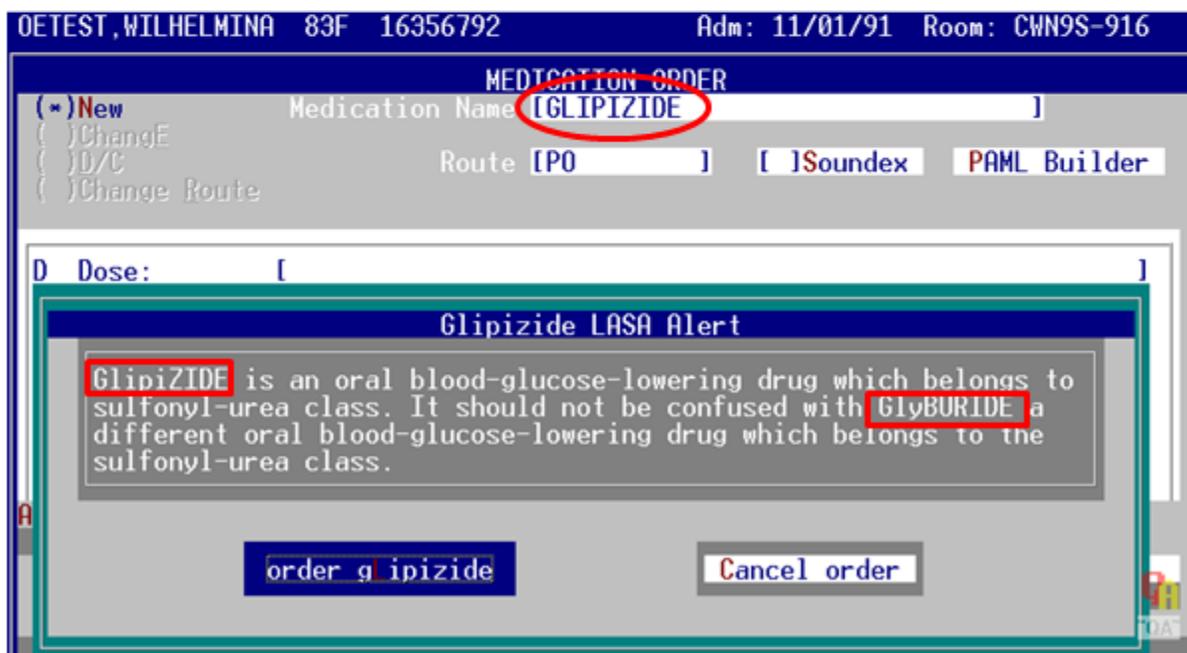
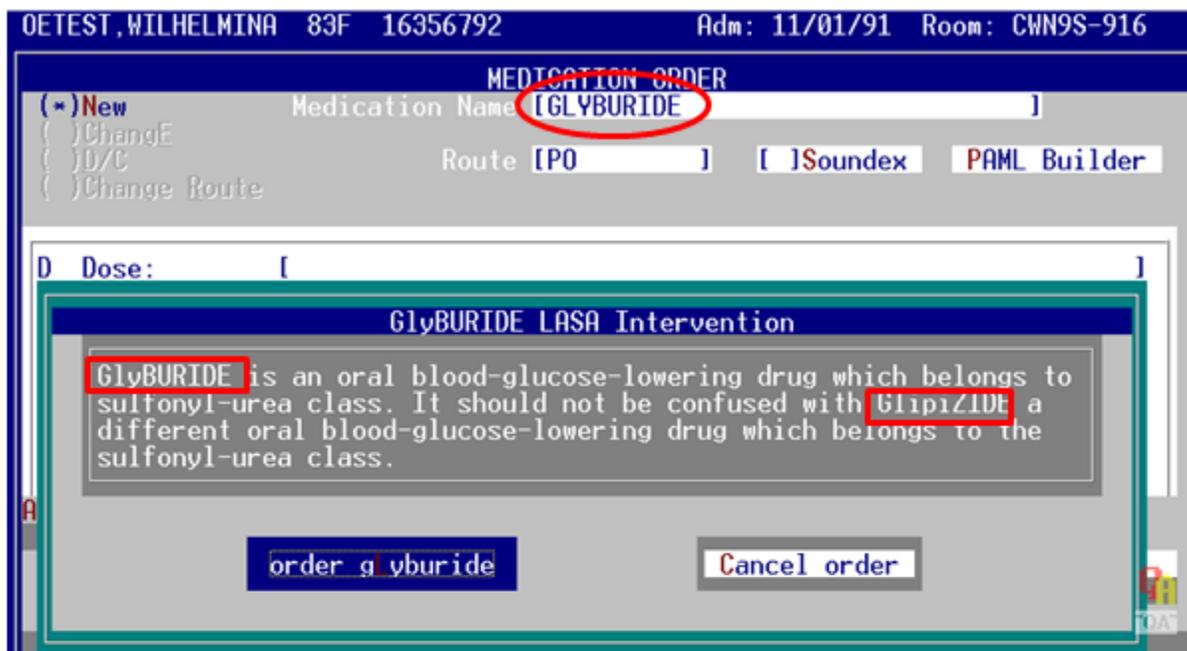
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<sup>17</sup> Kuperman GJ, Bobb A, Payne TH, Avery AJ, Gandhi TK, Burns G, Classen DC, Bates DW. Medication-related clinical decision support in computerized provider order entry systems: a review. *J. Am. Med. Inform. Assoc.* 2007;14:29-40.

<sup>18</sup> Nanji KC, Slight SP, Seger DL, Cho I, Fiskio JM, Redden LM, Volk LA, Bates DW. Overrides of medication-related clinical decision support alerts in outpatients. *J. Am. Med. Inform. Assoc.* 2013: amiajnl-2013.

<sup>19</sup> Campbell R. The Five Rights of Clinical Decision Support: CDS Tools Helpful for Meeting Meaningful Use.” *Journal of AHIMA.* 2013; 10:42-47.

<sup>20</sup> Horsky J, Phansalkar S, Desai A, Bell D, Middleton B. Design of decision support interventions for medication prescribing. *International Journal of Medical Informatics.* June 2013; 82: 492-503.

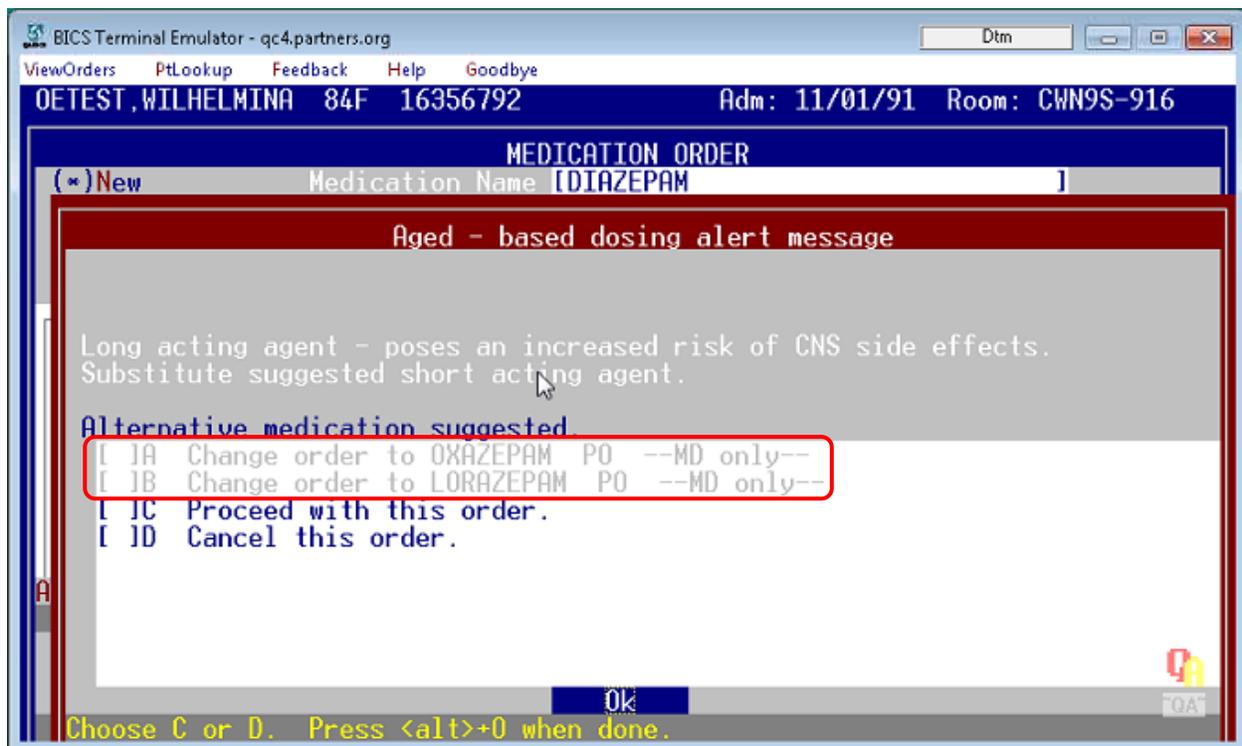


**FIGURE 14. LASA ALERT FOR GLYBURIDE AND GLIPIZIDE IN BWH INPATIENT BICS. THIS ALERT DRAWS ATTENTION TO THE LASA PAIR, BUT INDICATES ONLY THAT THEY ARE BOTH ORAL BLOOD GLUCOSE-LOWERING DRUGS IN DIFFERENT CLASSES. THERE IS NO INFORMATION TO ASSIST THE PRESCRIBER IN DETERMINING WHICH DRUG SHE OR HE SHOULD BE ORDERING.**

#### CDS: INCONSISTENT APPLICATION OF CDS

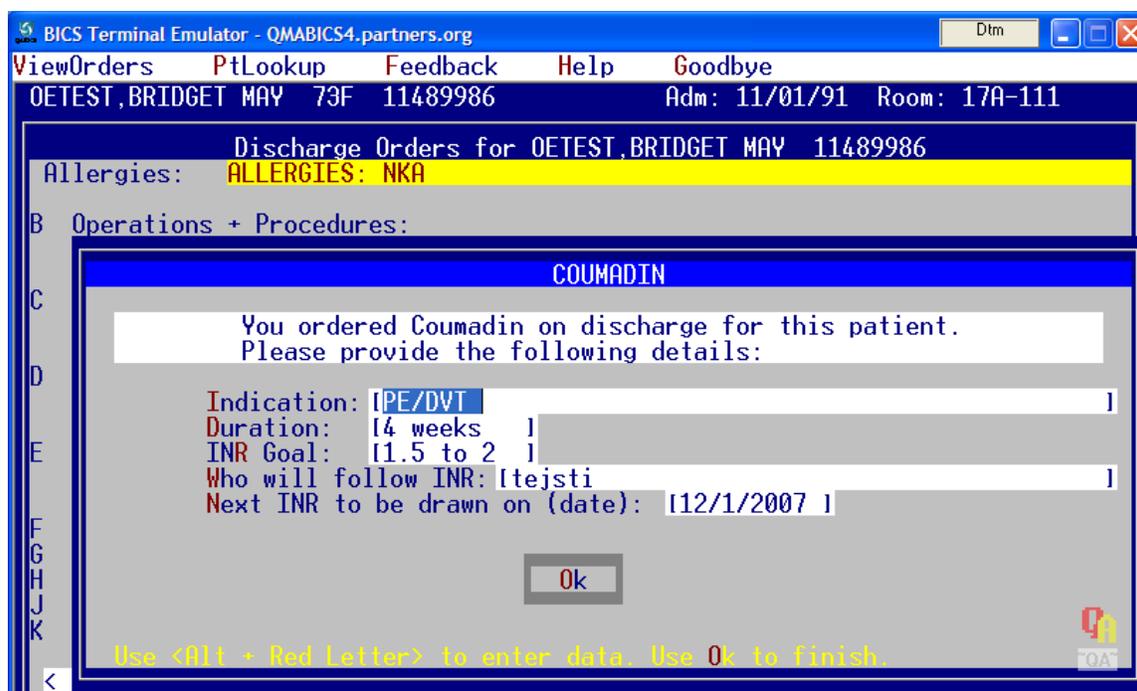
In some CPOE systems, CDS varies according to the user's role; other systems offer only one "track." In the BWH inpatient system, if a user attempts to order an inappropriate drug for a geriatric patient, an alert prompts the user to order a different drug. However, the suggestions and links to alternative drugs can be accessed only by users with certain privileges (physicians). In addition, the alert has different user privilege requirements than the system

itself. While a non-physician user might be able to inappropriately order diazepam, the CDS will not allow the non-physician to click on oxazepam or lorazepam to place an order from the alert text. This variability in CDS disrupts the clinical workflow and could prompt non-physicians to find a workaround.



**FIGURE 15. BICS ALERT ALLOWS USER TO PROCEED WITH INAPPROPRIATE ORDER, BUT PERHAPS BECAUSE OF AN UNINTENDED GLITCH, ALLOWS ONLY USERS WITH PARTICULAR CREDENTIALS TO CHANGE TO THE SUGGESTED ALTERNATIVE MEDICATION.**

Sometimes CDS may even vary depending on whether drugs are being ordered by brand or generic name. For example, when Coumadin was ordered at discharge in one system we studied, a screen asked the prescriber to specify an indication, duration, INR goal, and plans for INR follow-up (Figure 16). However, due to a programming error, the screen displayed those requests only when the order was entered as Coumadin, not warfarin (this oversight was discovered and corrected only after many months of the alert failing to fire on the generic).



**FIGURE 16. THIS SCREEN FOR INDICATION, DURATION, INR GOAL, AND PLANS FOR INR FOLLOW-UP APPEARED ONLY WHEN COUMADIN WAS ORDERED AND NOT WHEN WARFARIN WAS ORDERED. THIS WAS LATER CORRECTED.**

More disturbing was a finding from our team in an earlier study that *all* CDS was turned off for a system after a system upgrade. This remained undetected for months until our research team discovered the failure of any alerts to fire during tests of the CDS.<sup>21</sup>

In many systems, allergies can be entered as free text, rather than coded; this could be dangerous if a misspelled name prevents an allergy from being checked by CDS. Moreover, many "allergies" added are not true allergies, but unpleasant symptoms or intolerances that patients experience when taking a drug—worth noting but not necessarily contraindicating all future use of the medication. It is often the case that patients cannot remember all of their symptoms, and in an effort to be cautious, the prescriber may enter allergies that cause alerts to fire when unnecessary. Systems need better ways to differentiate these types of adverse effects, particularly to avoid creating the "noise" of hundreds of minor less serious reactions' alerts crowding out and causing clinicians to overlook the "signal" from more important and serious ones.

For effective CDS, it is important that alerts be triggered for ingredients of fixed-dose combination medications and that cross-sensitivity be checked. However, we identified some instances when an allergy alert failed to fire for individual ingredients. For example, if Augmentin (amoxicillin and clavulanic acid) is prescribed for a patient who is allergic to amoxicillin, the system should recognize that augmentin contains amoxicillin and fire an alert. Further, if the patient is allergic to penicillin and is prescribed augmentin (or just amoxicillin or Zosyn), the system should fire an alert due to the common cross reactivity of penicillin and amoxicillin. However, such alerts did not always fire in one of the systems we evaluated, and this has only recently been fixed.

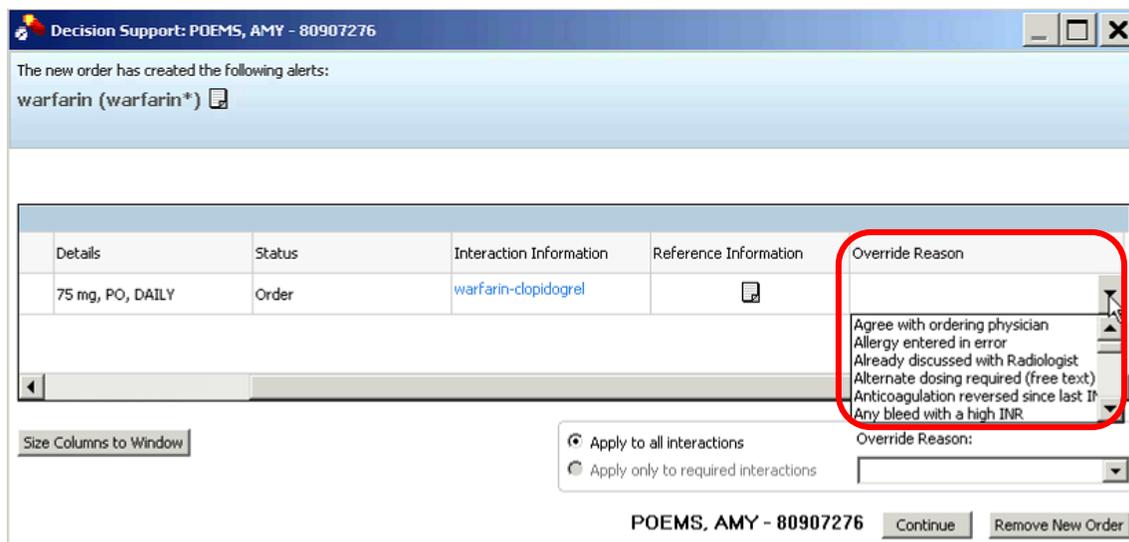
At BWH, all the alerts do not always fire for refills, orders from order sets, or orders from the favorites list. Because of this, the same drug for the same patient may or may not trigger an alert, depending on how the provider places

<sup>21</sup> Schiff GD, Amato MG, Egale T, Boehne JJ, Wright A, Koppel R, Rashidee AH, Elson RB, Whitney DL, Thach TT, Bates DW, Seger AC. Computerized Physician Order Entry-Related Medication Errors: Analysis of Reported Errors and Vulnerability Testing of Current Systems. *BMJ Qual Saf.* Accepted, Dec 2014. In press.

the order. When providers are not aware of these differences, they may wrongly assume they are protected by CDS. Although there may be reasons for such inconsistent and context specific firing (or non-firing) of alerts, it is still dangerous when prescribers do not understand the alert firing rules.

Often prescribers place duplicate orders because they cannot change a dose of a medication in the template or because they do not realize that a medication is included in the ordering template. For example, TPN (total parenteral nutrition) templates often include acid secretion blocking medications. If prescribers cannot see all the ingredients in the template, they sometimes order separate prescriptions for anti-acid medications. In some other cases, they seek to change the dose of a particular ingredient in the TPN template, but the change does not take effect and patients receive inappropriate doses. Moreover, order sets can be problematic because their individual ingredients and templates are often not linked to the “parent” drug; thus, there is the potential for them not to be updated when the “parent” drug changes or new decision support is added.

These are fundamental problems that need to be better addressed in the design and implementation of CDS in order to better understand and predict the behaviors of the systems and the clinicians. Understanding why alerts are ignored can help developers understand the limitations of certain alerts and assist them in better designing CDS. Forcing the user to indicate the reason for overriding an alert also encourages the user to stop to consider the alert and reflect on the best clinical practice, as well as capture useful data. However, requiring override reasons can also slow prescribers or lead them to enter inaccurate or meaningless information to bypass the requirement, thus needs to be implemented wisely and selectively. In addition to variable use of alert levels (non-interruptive, information-only alerts vs. interruptive, “hard stops” that require the user to provide a reason in order to proceed), there is also variability in how systems capture override reasons in response to alerts. Some systems have long drop-down lists of coded reasons for responding to an alert, some of which are totally irrelevant to the type of alert that the user was seeing. Figure 17 below illustrates how one system presented override reasons. Even though this is a DDI alert, the response options include “the allergy being entered in error” or “already discussed with radiologist,” which does not make sense or apply in the context of the alert. This can be problematic because physicians may just pick the first item on a list, and are less likely to scroll through a list of irrelevant reasons to find one that is appropriate for that situation.



**FIGURE 17. ONE INPATIENT SYSTEM’S DECISION SUPPORT AND OVERRIDE.**

## CDS: VARIABLE USE OF COMMERCIAL DRUG DATA COMPENDIA VS. LOCAL CUSTOMIZATION

Sites generally did not utilize the commercial drug compendia and their bundled CDS features “out of the box” without performing their own modifications. Commercial medication knowledge bases were not always consistently used to drive drug name choices. Most of the sites we studied maintain their own knowledge base

containing information on drugs, doses, and uses, especially in the inpatient setting, although these sites as academic centers may not be perfectly representative of local implementations elsewhere. We found institutions needed to invest considerable resources in maintaining their local drug databases, which they felt was needed to ensure consistency with local formulary and drug availability and ordering warnings and restrictions.

### CDS: INCONSISTENCIES IN FIRING IN CDS

We uncovered an unexpected glitch in one system (the BWH outpatient system) in which certain alerts fire inconsistently when drugs are ordered from Practice Favorites (instead of the standard drug dictionary). In addition, drugs that are no longer on the market could still be ordered from the Practice Favorites list (e.g., non-HFA Albuterol inhaler).

Further, we found inexplicably that no geriatric dosing alert fired the first time the user ordered a particular drug from the Practice Favorites, yet if the user ordered the same drug a few minutes later from the same Practice Favorites list, the geriatric dosing alert would usually fire. This alert, however, would always fire when the medication was ordered from the Medication Dictionary (see Figure 18). Inconsistent alerting and intermittent bugs like these may be dangerous, as prescribers increasingly rely on alerts to guide their prescribing.

Figure 18 consists of two panels, A and B, illustrating a software bug in the BWH outpatient LMR system. Panel A shows the 'Add New Medication' screen. The medication 'IBUPROFEN 600MG, 1 PO TID' is selected from the 'Practice Favorites' list, which is circled in red. The 'Strength & Form, Take' field shows '600MG TABLET take 1 Tablet(s)' and the 'Frequency' is 'TID'. Panel B shows the medication details screen for 'IBUPROFEN 200 MG TABLET'. The 'Strength & Form, Take' field shows '200 MG' and the 'Frequency' is 'Q8H'. A geriatric dosing alert is displayed, stating: 'Geriatric Dosing - appropriate doses and frequencies for geriatric population: doses - 200 MG, 400 MG, 400-600 MG, 400-600 mg; ibuprofen increases the risk of CV and GI events (black box warning), as well as renal failure. If used, especially long-term, monitor CV, GI'. The alert is highlighted in yellow. Red arrows point from the 'Practice Favorites' selection in panel A to the medication details in panel B.

**FIGURE 18. IN THE BWH OUTPATIENT LMR SYSTEM, ALERTS FAILED TO FIRE IF THE DRUG IS ORDERED FROM “PRACTICE FAVORITES” (A), BUT DO FIRE IF THE DRUG IS ORDERED FROM THE STANDARD MEDICATION DICTIONARY (B).**

In another disconcerting example, it was found that a particular drug-drug interaction (DDI) did not fire if one of the drugs is reactivated (instead of ordered anew). When a DDI alert did not appear for metoclopramide and venlafaxine, an astute clinician at BWH reported this to the Team Coordination Group communication support system (TCS), believing it to be a malfunction. The patient had already been on venlafaxine for over one year, and no DDI alert appeared when the prescriber ordered metoclopramide. The pharmacist had called to warn the prescriber that there was a major drug interaction and that metoclopramide was contraindicated, but the DDI alert did not fire in the CPOE system because the ordered medication (metoclopramide) was reactivated from the inactive medication list, and alerts do not appear in this system when drugs are reactivated. The prescriber, the pharmacist, and most healthcare providers using this system, were unaware that ordering a “reactivated” drug bypasses the firing of an alert. The situation went unnoticed for months until it was finally reported, but we found it had not been fixed. This type of finding is particularly worrisome, because while prescribers often ignore alerts in many circumstance, they also often come to rely on them in other situations.

### INTEROPERABILITY: WITHIN ORGANIZATIONS, SITES, AND SYSTEMS (E.G., INPATIENT TO OUTPATIENT)

Limited interoperability between systems was repeatedly reported as a problem. With respect to CDS, various issues were uncovered in each of the systems. Many had inconsistencies in alerts (types, displays) between inpatient and outpatient systems. Again, this could result in confusion or erroneous expectations for providers who practice in both settings. Standardizing characteristics across interfaces would allow users to interpret alerts more intuitively and respond in a more meaningful manner. Technological barriers, such as lack of access to data from one setting to another, fragments information and hampers the provider's ability to make the best decision for the patient. In one setting we found that, in addition to two different CPOE systems being used for inpatient vs. outpatient orders, that a 3<sup>rd</sup> system was in place for "discharge" drug prescriptions.

While the move toward better interoperability for information sharing across networks at the state, regional, and national level holds promise to alleviate this problem, a clear short-term deficit we identified is the lack of seamless information transfer between settings even in the same institution. Notably, we found that providers are often unaware that they do not have access to all of their patients' medications or other information, especially within a hospital network. Several providers we interviewed were also surprised by the differences in the way medications needed to be ordered or the capabilities for CDS that depended on the setting in which the EHR was accessed. As noted above, another aspect of this inpatient-outpatient divide was related to how discharge medications (i.e., outpatient medications being ordered in the inpatient setting) were handled, and one system, for example, had to develop an entirely different and stand-alone discharge medication module to accommodate this need, which users described as poorly functioning, in addition to being different from the inpatient or outpatient systems they were used to using.

### INFORMATION FLOW OR COMMUNICATION BETWEEN PRESCRIBERS AND PHARMACISTS: FAILURE TO COMMUNICATE MEDICATION DISCONTINUATIONS TO PHARMACY

CPOE technology should also take into account the need for information to be shared between CPOE systems and pharmacy systems. For example, when a provider discontinues a drug in the CPOE system, that information needs to be relayed to update the profile of the dispensing outpatient pharmacist. Our evaluations and interviews revealed, nearly universally, that discontinuing an ordered medication in the CPOE system does not automatically or systematically communicate this discontinuation to the outpatient pharmacy that the prescription was originally sent and is continuing to dispense refills. This creates a serious vulnerability that discontinued medications—even those discontinued due to a serious adverse reaction could be repeatedly dispensed or refilled.

Thus when a prescriber discontinues a medication in the EHR, it is removed from the active medication list, and the system therefore "knows" that the drug was discontinued. However, in most systems this information is not transmitted to the pharmacy. The pharmacy may, in efforts to maximize adherence, even actively reach out to contact the patient to refill a drug even though the doctor has discontinued it in the EMR (e.g., due to allergic reaction). This is also dangerous because prescribers may be unaware that the pharmacy does not receive a discontinuation notice in most CPOE systems and are unaware of the continuing refill in that patient. At one site we studied (and also in the US Department of Veterans Affairs Health System), discontinuation messages are in fact transmitted to the pharmacy. However, at that same site doctors nonetheless often fail to enter the stop order into the system. While SureScripts has a structured channel for transmitting such discontinued medication orders, it is largely unused both at the ordering (CPOE) end as well as the receiving end (pharmacy).

Patients sometimes attempt to pick up a medication from a pharmacy only to learn that the prescription was not successfully transmitted. Prescribers should receive notification when an order transmission is successful.

## TEMPORARILY PLACING ORDERS “ON HOLD”

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Systems vary in their handling of hold orders. Some have options to suspend drugs only when patients go to the operating room, some systems can hold orders for only a few drugs, and other systems have the “hold” function for all drugs. In the BWH inpatient CPOE system, hold orders are possible, but the inconsistent (even quirky) workflow is confusing for clinicians. Changing drugs in this system usually starts with the “change” button and then selecting the drug; however we found that surprisingly the “hold” button is disabled when warfarin is selected. However, in the workflow for holding drugs, the “hold” button must be clicked before selecting a drug.

## PATIENT IDENTIFICATION: WRONG-PATIENT ERRORS

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Ordering a prescription for the wrong patient is a well-documented problem, even historically with paper prescriptions before implementation of CPOE.<sup>22</sup> However, there is unique vulnerability in CPOE because of the ease by which the wrong patient’s chart can be accessed. One institution on our CPOEMS initiative has done considerable work in analyzing and quantifying this problem, as well as implementing preventive measures. Using retract-and-reorder events as a marker for wrong-patient errors, those researchers found that of the 9 million electronic orders placed at their institution in 2009, 6,885 were retract-and-reorder events. Of these, 5,246 (76.2%) were wrong-patient errors. To prevent such errors, they implemented a requirement that physicians must enter the name, date of birth, and sex of the patient each time they switch to a new patient record, which resulted in a 41% reduction in wrong-patient errors, although it imposes a substantial added time burden on the physician.<sup>23</sup> Other systems do not have similar safeguards, though other methods—such as added signing requirements before order processing, drug-indication checking, and even placing the patient’s picture on the CPOE screen—have been demonstrated to decrease wrong-patient errors.<sup>24</sup> Indication alerts also have the potential to create crosschecks to avoid or detect wrong patient errors (“Why are you giving me this drug for gout—I don’t have gout”).<sup>25</sup>

## MEDICATION DISCONTINUATION AND RECONCILIATION

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Medication reconciliation is a CPOE-related area of that is in considerable disarray—both in terms of the software design and workflow of the entire team. While not directly part of the scope of this project, these issues arose multiple times as we sought to identify and understand CPOE-related errors.

Fundamentally, drugs entered on a patient’s medication profile can have two different possible meanings or constructs: 1) as a medication order intended to be transmitted (electronically, by fax, or via printed prescription) to the pharmacy, ordering the dispensing of a medication; or (2) as a historical record, populating a patient’s medication profile but not generating an order. There can be considerable variation and lack of understanding in how systems and individual prescribers handle the distinction between these two types of entries.

Confusion and problems can arise when physicians enter medications that have been prescribed by a different physician (which the second physician prescriber may or may not have accurate information about) or when non-prescribers (e.g., medical assistants [MAs]) enter and revise orders, as they are increasingly doing with the implementation of reconciliation requirements as part of meaningful use.

The BWH LMR reconciliation system requires staff to document whether the patient is “taking” the medication. This has been a source of considerable confusion, as there is no standardized operational definition of the word

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<sup>22</sup>Oops, Sorry, Wrong Patient! Applying the JC “Two-Identifier” Rule beyond the Patient’s Room. *Acute Care ISMP Medication Safety Alert!* June 3, 2004. <http://www.ismp.org/newsletters/acutecare/articles/20040603.asp>

<sup>23</sup>Adelman JS, Kalkut GE, Schechter CB, Weiss JM, Berger MA, Reissman SH, Cohen HW, Lorenzen SJ, Burack DA, Southern WN. Understanding and preventing wrong-patient electronic orders: a randomized controlled trial. *J Am Med Inform Assoc.* 2013;20:305–310.

<sup>24</sup>Galanter W, Falck S, Burns M, Laragh M, Lambert BL. Indication-based prescribing prevents wrong-patient medication errors in computerized provider order entry (CPOE). *J Am Med Inform Assoc.* 2013 May 1;20(3):477-81

<sup>25</sup>Galanter WL, Bryson ML, Falck S, Rosenfield R, Laragh M, Shrestha N, Schiff GD, Lambert BL. Indication Alerts Intercept Drug Name Confusion Errors during Computerized Entry of Medication Orders. *PLOS ONE.* 2014; 1-7.

“taking” vs. “not taking” to guide prescribers in using this module. During reconciliation, staff sometimes enter that the patient is “not taking” the drug; however, that response does not clarify whether the drug has not been prescribed, the provider discontinued the medication, or the patient is choosing not to take the drug, is not taking the drug *regularly*, or is taking the wrong regimen.

Many medications discontinued represent prescriptions that the patient is no longer actively taking. Thus, discontinuations are often part of medication reconciliation, but this can be confusing when such information is entered by non-physician staff. Non-physicians may also enter new medications on the active medication list in an effort to capture the medications a patient may have been prescribed by other or external providers, even though they are not being sent to the pharmacy. The CPOE system often forces MAs to make choices beyond their level of knowledge. They might attempt to enter vitamin D, which a patient states she is taking, but the system does not allow them to write “vitamin D,” as they must enter and choose between ergocalciferol and cholecalciferol, drug names and distinctions they (and many physicians) do not understand (for more on this see section on drugs discontinued in error). We found (particularly in our drug discontinued due to errors study, see below) that many errors were related to the newly introduced roles for MAs and other non-physician staff in the placing of medication information using medication reconciliation drug ordering or discontinuing functions.

Through our largely unrestricted access to our own organization's CPOE records, we were able to conduct a retrospective study of outpatient ordering 2011-2013. We identified when a drug was discontinued due to the reason “error (erroneous entry)” (Figure 19a) and linked that to the ordering of a new drug on the same day. We found 16,790 such events and reviewed data to better understand these “switches” as potential CPOE error events.

We discovered that non-providers (i.e., MAs) were sometimes documenting discontinuations and indicating the reason as “error (erroneous entry).” We could only hypothesize their reason(s) based on other information in the patient chart. For example, one of the most common changes in new orders that replaced discontinued orders was a change in dose. Further, non-prescribers often entered drugs (e.g., over-the-counter drugs, vitamin D) incorrectly as a historical record during medication reconciliation, with physicians later discontinuing that medication due to “error (erroneous entry).” Additionally, not all of the apparent “switches” were cases of one drug being discontinued and the new drug being ordered. For example, oxycodone and docusate sodium are often prescribed together and also usually discontinued simultaneously. Thus, both drugs were prescribed and discontinued in error; one was not a replacement for the other.

### CPOE ERROR AND DESIGN ISSUES: CONCEPTUAL INSIGHTS AND TAXONOMY

Our detailed review of data sources from BWH and the collaborating sites, uncovered a myriad of issues with the potential for causing errors in the CPOE systems evaluated. These issues can be classified and understood in a variety of ways. While we have developed a more granular taxonomy of CPOE-related issues, we also believe a high level understanding of generic IT issues can be helpful. We define and describe various types of general issues encountered such as tradeoffs, design flaws, bugs, workarounds, and hidden functions.

#### TRADEOFFS

*Tradeoffs* are intentional decisions whether to include a particular feature or function when creating and implementing a CPOE system, and are thus different from a *bug*. They are a necessary part of the decision-making process when designing a system, but can unfortunately introduce errors. Because of the socio-technical nature of CPOE systems and the varying needs and resources of institutions, as well as resource constraints, some features or functionalities are consciously excluded. For example, the limited space on a screen restricts the amount of important information that can be displayed, requiring CPOE system designers and institutional decision makers to choose what information to include and where to include it. Another example of a tradeoff is balancing the risk of alert fatigue posed when an alert is programmed to fire for every possible issue. This challenges designers and other decision makers to judiciously determine which issues will trigger an alert. Tradeoffs occur at both the institutional level and the design stage. Decision makers at each institution often also choose which features in CPOE to activate based on programming costs.

## B. PROBLEMS IN IDENTIFYING, COLLATING, LINKING, ANALYZING, SHARING, AND LEARNING FROM CPOE-RELATED ERRORS

A key finding from our study is that none of the systems we evaluated had a single, centralized, dedicated database for collecting, tracking, and learning from CPOE safety issues. While this posed significant challenges for the CPOEMS investigators in collecting the types of local data we sought for this project (and led our team to use a mix of methods and sources described above), the more serious concern relates to broader implications for CPOE monitoring, learning, sharing, and improvement, which requires systematic feedback to local and national designers and vendors, as well as transparency and oversight.

Because there is currently no efficient organized local or national system (local or national) for systematically gathering, analyzing, and sharing data on CPOE risks and medication errors, it was necessary to creatively tap into a variety of often-siloed information sources at each institution. Thus, in addition to collecting and cataloging the *types of errors* we uncovered, we devoted considerable effort to identifying and describing various potential *sources of data* that we postulated might have data and reports related to CPOE errors and problems. These included: a) institutional safety reports, b) information technology (IT) help desk user calls, c) health IT (HIT) or CPOE system change requests and changes implemented, d) pharmacy intervention logs (order corrections by pharmacists), e) clinical decision support (CDS) requests, additions, performance monitoring, f) error reports to vendors/developers, g) evidence of erroneous orders from analysis of discontinuations due to errors in initial orders, and h) various “vulnerability” tests of known issues (e.g., Leapfrog<sup>26</sup> or BWH MedMarx testing scenarios [Appendix C]).

As specified in the FDA BWH CPOEMS task order, we conducted a comprehensive in-depth review of these sources related to Brigham and Women’s

### BUGS

A computer system *bug* is a hidden issue or a glitch that prevents the system from working as it was designed. Bugs can be congenital (the bug always existed) or can be introduced after initial implementation of a system, particularly during upgrades.

*Congenital bugs*, as described by our internal team, are issues or features that never worked properly. For example, when a user ordered dexamethasone in the BWH inpatient BICS system and selected “taper” as a dose, the system did not take the user to a screen to enter the parameters of the taper. Thus, the order simply indicated “taper” for the dose, which is an invalid order.

Bugs introduced with upgrades are often termed *regression errors*—functions that used to work but now do not. It is vital for IT experts ensure that a software update works with all other functions. Bugs can result from poor design or a lack of update testing. For example, an update in one system created a bug that allowed incomplete orders to be saved when the user was attempting to escape from the order. An upgrade in another system changed a patient’s medication allergies (oral contraceptives caused seizures) to “Not found” instead of the name of the drug.

Some bugs we identified were *constant* – they occurred every time a particular function was accessed. These bugs were generally more readily spotted and fixed, because users would often complain about them and developers could readily reproduce them. The sites in our study also encountered *special* and *intermittent bugs*. We defined *special bugs* as those that occurred consistently but only in special circumstances, such as bugs that affected only medical student orders, or bugs that affected only a single drug or drug/dose combination. These were harder to identify and root out because they happened infrequently in a module that otherwise worked correctly; however, once the special circumstances were identified, they were reproducible. For example, orders from some users (e.g. medical students) require co-signing before they are implemented. Due to a bug, some discontinuation orders that should have required cosigning were automatically approved by the system. The third and most difficult category to reproduce and fix was *intermittent bugs*, which occurred only some of the time. Most of the bugs that we address here have already been fixed. One example of an intermittent bug found in LMR was one that caused alerts to fire inconsistently when medications are ordered from the Practice Favorites list (Figure 18).

<sup>26</sup> <http://leapfroghospitalsurvey.org>. 2014, The Leapfrog Group.

Hospital (BWH). We generated a variety of primary and secondary data related to potential CPOE errors in BWH's two pioneering CPOE systems – the Brigham Integrated Computerized System or BICS (inpatient) and the Longitudinal Medical Record or LMR (outpatient). We also obtained information from the other five collaborating sites, examining any existing data sources that were available. These joint efforts were quite productive, and each site identified and shared at least one highly useful source of CPOE medication error information. In the following section we detail the “macro level” issues and findings related to problems in identifying, collating, linking, analyzing, sharing, and learning from CPOE-related errors, and the next section details special studies we performed for this project.

## ERROR REPORTING SYSTEMS, PRACTICES, AND CULTURE

None of the collaborating institutions had a systematic way to identify, collect, and track issues and errors related to CPOE. Instead, such data is either non-existent or siloed in various compartments and departments that do not routinely crosslink and share this information. Typically learning takes place only after an error has occurred, and each site has its own mechanisms for identifying and reviewing errors. Organizations require systems to uncover existing issues so users can anticipate and developers can learn from significant past errors and vulnerabilities. Despite rudimentary efforts reflected in some of the sources of information, no systems had in place all of the data elements that would appear to be essential in safeguarding systems and learning from errors.

Even better-developed reporting systems, such as institutions' spontaneous error reporting systems, suffered from a variety of shortcomings noted below, and were infrequently used to identify problems to improve CPOE. Further, due to the voluntary nature of the reporting systems (similar to the voluntary reporting of adverse reaction to drugs) there is significant underreporting of many errors and error types. User frustrations and vendor-level issues with the CPOE systems should also be systematically documented, but are currently not well captured or available for either

### DESIGN FLAWS

Flaws are unintentional design defects in the software architecture that could have adverse consequences. For example, if IT designers create a date field that simply allows the entry of any real date instead of limiting the field to a current or future date, users may enter in a date in the past, causing confusion. Users at BWH noted that they could enter a start date in the past in the NICU OE system. This may have been initially designed to allow verbal orders, but has since been changed so that start dates in the past could not be entered. Design flaws in CPOE systems should be addressed but are often perpetuated because of institutions' limited resources or these fixes are superseded by other priorities.

### WORKAROUNDS

CPOE systems are not always programmed to accommodate special cases, forcing prescribers to create workarounds. Workarounds are behaviors locally constructed to circumvent design issues that prevent a given action or interrupt a work flow. For example, we found that one system required prescribers to write an incorrect weight for their patient in order to decrease a medication dose. This, in turn, confused the pharmacists processing the orders, because multiple weights were listed for the patient. Workarounds may be used to overcome design flaws, hidden or unapparent features, and constant bugs. Comments fields and special instructions are frequent workarounds when prescribers are unable to find their intended medication or sig. While some workarounds are processes created for special cases, many are standard processes used in almost all cases. For example, some physicians would like their nurses to see parts of records that are not usually available to nurses, so physicians share their passwords or arrange for another workaround. Another example of a workaround created for standard use was the occasional incorporation of suggestions and warnings into the drug name field, and an observed instance of this is further discussed in a later section of this report.

### HIDDEN, UNUSED, OR UNDERUTILIZED FUNCTIONS

Systems often have functions that are not apparent, underappreciated, and underutilized. An example of this is the ability to switch the search functions in one outpatient CPOE system, a function of which many users are unaware (Figure 2). CPOE features are often underutilized due to a lack of training, confusing interfaces and vague options. Some systems have the ability to discontinue and reactivate drugs. We found that one system allowed the user to discontinue/cancel or suspend a drug, as well as copy/reorder, unsuspend, and reinstate the drug. These terms are similar and the options force the provider to stop and consider what the different options mean, which slows the ordering process and allows room for error.

## CPOE SAFETY – FINDINGS AND ISSUES: PROBLEMS IN IDENTIFYING, COLLATING, LINKING, ANALYZING, SHARING, AND LEARNING FROM CPOE-RELATED ERRORS

internal (organizational, vendor) or external (FDA, researchers, public) review.

One example of a particularly disappointing finding was the lack of usable pharmacy intervention logs, which were often kept largely as "productivity counts," records of activity, rather than meaningful logs with useful information or insights about types of errors identified by pharmacists as they reviewed each prescription. While pharmacists often intervene on orders to ask for clarification or to convey problems with a prescription (some of which may be caused by CPOE issues), we found that none of the pharmacist intervention logs currently being kept across all the sites studied contained information in a structured and coded way to allow for learning from the issues being addressed, thus hindering the ability to improve CPOE systems. Such information could be a valuable source of information about types of problems that are either caused by CPOE or might be prevented by better-designed ordering screens and decision support. Here we are referring to lack of internal feedback systems. Further, systematic feedback from outside pharmacies that encounter many thousands of problematic prescriptions (requiring clarification or correction calls to the prescriber) are completely disconnected from local CPOE feedback, monitoring, and improvement. This creates much residual frustration for all parties (physicians, pharmacists, patients) when problem prescriptions remain unfilled or create additional work (e.g., telephone calls, re-working).

### VARYING/POOR QUALITY OF ERROR REPORTS

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Further, the quality and consistency of the reports for those errors that *are* reported varied widely. Two recurrent issues we identified in reviewing hundreds of these reports from BWH and our collaborating sites were: a) lack of accuracy in the classification of type of error on the safety report coding taxonomy, and b) the quality and details of the report narrative, and whether it contained sufficient information to assess whether and how CPOE had contributed to the medication error.

For example, we reviewed all of the BWH error reports from January 2010 to February 2014. Out of a total of 35,484 reports in this time period, 5,321 reports were medication related, and 986 were classified by the reporters as being related to medications in the "ordering and prescribing" phase. Our pharmacist reviewers found that 345 of these 986 reports were not CPOE-related and were often not actually in the "ordering and prescribing" phase. Hence, many of such reports are likely misclassified. These 345 reports included other types of errors, such as dispensing and administrating errors (e.g., nurse entered the wrong number in the pump). While some represent HIT-related issues as they may involve issues related to input of data into a computer, they are not errors in the medication-ordering phase. Thus, one function of more meaningful review and use of these reports would be for quality control to improve reporting systems and provide feedback to reporters. At the very least, consistent operational definitions and a minimal shared understanding of narrative descriptions are needed.

### FAILURE TO DOCUMENT CPOE-RELATED ERRORS IN THE MEDICAL RECORD

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Related to failure to report many errors, we also found a lack of documentation of CPOE errors or issues in the medical record, even for cases where errors had clearly occurred. For example, in our retrospective study of medications discontinued in error (as stated by the person discontinuing the drug), there was not a single description or mention of an error in any of the 205 charts we reviewed. (This provided the impetus for the more informative prospective study discussed below.) Ideally, prescribers should write a note in the chart when they prescribe the wrong drug and explain what happened (e.g., "pharmacy called and told me that I prescribed a drug intended for another patient, which I have discontinued," or it could even be automatically generated when the reason for drug discontinuation is documented in CPOE).

### LIMITED ABILITY TO IDENTIFY, CROSS-REFERENCE, AND AGGREGATE DISPARATE SOURCES

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Our review of the error reports and reporting systems across the sites revealed that there is no centralized repository for the information that is collected. We learned that each site and area within each site uses different terminology and processes in its efforts to review medication errors and CPOE issues. This information remained in multiple "silos" rather than being collected in and accessed through a centralized location or database. Further, multiple different committees and "owners" oversaw the CPOE-related reports and information.

## CPOE SAFETY – FINDINGS AND ISSUES: PROBLEMS IN IDENTIFYING, COLLATING, LINKING, ANALYZING, SHARING, AND LEARNING FROM CPOE-RELATED ERRORS

This absence of any centralized data repository to collect CPOE issues limits the ability to analyze, prioritize, and address actual or potential errors. The involvement of several different domains, committees, and teams (pharmacy, IT, safety, CDS committees) and limited standardized taxonomies for coding such information meant that information was fragmented both within and across the sites and was hence not interoperable.

### LIMITED STANDARDIZED TAXONOMIES FOR CLASSIFYING CPOE ERRORS

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Closely related to the problem of collating and cross-referencing errors and problems is the need to have a standardized taxonomy to classify, describe, and track them. As other HIT and medication safety issues warrant similar attention, there is no need for a separate standalone system for CPOE errors, as that would likely result in further fragmentation and redundancy. However, a more granular and usable taxonomy to sub-classify types of CPOE errors is vital. Though AHRQ Common Formats provides a taxonomy for errors, our review of errors classified with Common Formats revealed the taxonomy to be poor due to a lack of specificity regarding CPOE related issues. Others have also found it to be cumbersome and confusing.<sup>27</sup> Even ad hoc approaches to a more granular categorization was not evidenced from the reports we reviewed from the collaborating sites, as most had never even delved into the pool of reports sitting in their error and other HIT databases. Thus our project represented a useful first look, generated a number of important findings related to types of CPOE errors, and catalyzed the further development of a tool we had already created.

The taxonomy developed and used for this project was based on the BWH MedMarx CPOE Error taxonomy tool that was based on a classification initially developed for a National Patient Safety Foundation (NPSF)-funded project examining CPOE errors reported to the U.S. Pharmacopeia Convention (USP) MedMarx Medication Error reporting database, and substantially revised during this current project.<sup>28</sup> A critical finding from the CPOEMS project revision of this taxonomy was the need for refinement in classification of “what happened” in describing a CPOE error. This has two components: 1) what happened to the patient, vs. 2) what happened within the CPOE system; these are distinct elements in describing an error. We have now revised this earlier taxonomy for and based on the CPOEMS initiative, and our pharmacists and team have successfully used this new taxonomy to categorize the error reports we collected from our own and collaborating institutions (Appendix C).

### POOR MAINTENANCE, AVAILABILITY, TRANSPARENCY, AND TRACKING OF SYSTEM MODIFICATION LOGS

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We examined changes to CPOE systems made in response to errors and problems that had been uncovered at BWH and inquired about the availability of this data elsewhere. It seemed to be a reasonable expectation that such logs would be readily available and would be a good source of types of potential and actual CPOE errors. However, we found no official or standardized documentation of the features and modifications made to CPOE systems, and wide variation in the systems that did exist. There was a universal lack of a single official way or location in which to document the features and modifications made to CPOE systems and the reasons for these changes (i.e., to correct a particular reported bug or error-prone screen or feature) and connect this to safety reports in an organization. Ideally CPOE designers should document requests and reasons for changes in a standardized format.

This was true for all the sites. Even in our own home-grown academic-based system where we had unrestricted access to all internal documents and information, we found it challenging to locate a complete, accurate, and up-to-date history of how the system evolved, including the problems reported, features requested, and changes implemented. The extent to which commercial vendors do keep such logs of problems reported to them is unknown, and such information is not shared in any way. However, at the local institutional level, experience and knowledge regarding changes are needed, but lacking.

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<sup>27</sup> Schneider EC, Ridgely MS, Meeker D., Hunter LE, Khodyakov D, Rudin R. Promoting Patient Safety Through Effective Health Information Technology Risk Management. RAND Health, Office of the National Coordinator for Health Information Technology, May 2014.

<sup>28</sup> Schiff GD, Amato MG, Egale T, Boehne JJ, Wright A, Koppel R, Rashidee AH, Elson RB, Whitney DL, Thach TT, Bates DW, Seger AC. Computerized Physician Order Entry-Related Medication Errors: Analysis of Reported Errors and Vulnerability Testing of Current Systems. *BMJ Qual Saf.* Accepted, Dec 2014. In press.

### DIFFICULTIES IN AND FAILURE TO MONITOR BEHAVIORS OF CDS ALERTS AND PROVIDER RESPONSES

CDS alerts varied widely across the sites. Based on our team’s earlier work and observations using the CAT and testing scenarios as well as information gleaned from interviews in this project, it was clear that the number and types of alerts were highly variable particularly for DDI, dosing limits, drug-disease interactions, and duplicate drug alerting.

Although such information is basic for monitoring the performance of their CDS systems, none of the sites could readily generate simple reports listing the alerts in place, the conditions under and frequency with which they “fired,” and—most importantly—how often they were overridden and the reasons why. At one site with a well-developed commercial system, one diligent clinician-informatician had, with much effort, created a query to run such reports. However, because he recently retired, no one was able to generate such valuable reports. The BWH Centers for Safety and Research in Therapeutics (CERT) has an advanced research project examining CPOE alerts, overrides, and their appropriateness as well as linking such responses to human factors in the design of selected alerts (Appendix F briefly summarizes some of the published information from this research).

### NON-STANDARDIZED AND CONFUSING SCREENS CAPTURING REASONS FOR DRUGS DISCONTINUED BECAUSE OF ERROR IN INITIAL ORDER

At BWH, one method used to identify errors was from medications discontinued due to “Error (erroneous entry)” (Figure 19a). This reason suggests that some of the errors may be due to CPOE-related issues although this code was selected for many different reasons, as described in Special CPOEMS Error Studies section below. However, our prospective and retrospective study of the times and ways prescribers use this category of discontinued in error demonstrates that there was considerable confusion about the definition and when this reason should be entered. Another system has three more specific reasons for discontinuation that may be CPOE-related: correct ambiguous order, improperly composed order, and inadequate information (Figure 19b).

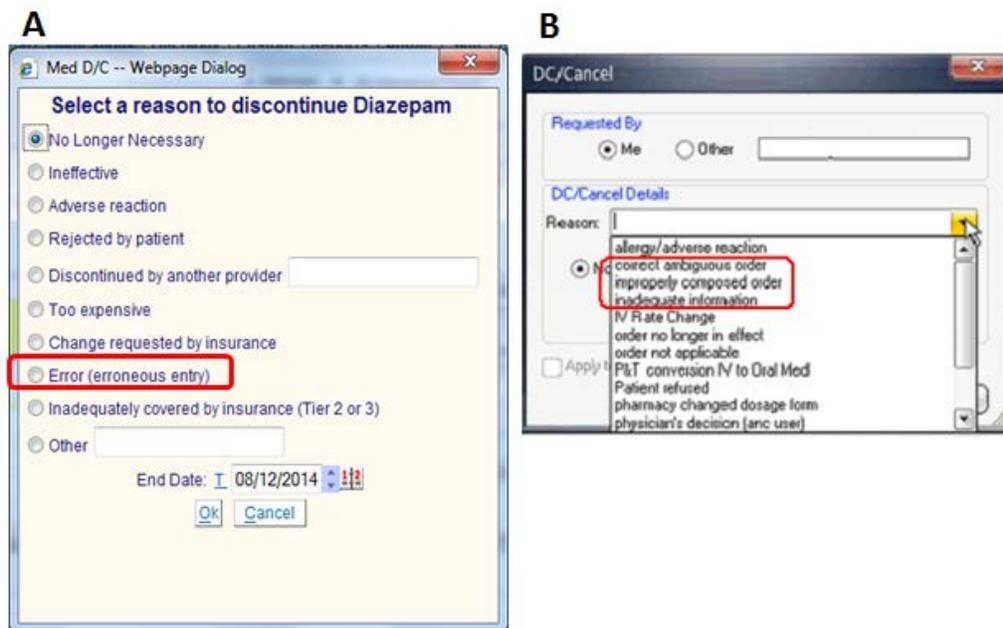


FIGURE 19. SCREENS OF REASONS TO CHOOSE WHEN DISCONTINUING A MEDICATION IN (A) BWH OUTPATIENT SYSTEM (LMR) AND (B) A COLLABORATING SITE’S SYSTEM. THE COLLABORATING SITE’S DISCONTINUATION SCREEN DISPLAYS THREE DISCONTINUATION REASONS THAT COULD BE CPOE-RELATED. IN THE SCREEN FOR DISCONTINUING MEDICATIONS IN LMR, “NO LONGER NECESSARY” IS THE DEFAULT REASON SELECTED WHEN A

**PRESCRIBER CHOOSES TO DISCONTINUE A MEDICATION, SO THE CLINICIAN IS REQUIRED TO ACTIVELY SELECT “ERROR (ERRONEOUS ENTRY).”**

DIFFICULTIES IN CREATING AND USING “TEST PATIENTS” FOR SCENARIO TESTING BEHAVIOR AND VULNERABILITY EVALUATION

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Though three of our six site coordinators reported no difficulties in creating test patients in their systems, our walk-throughs of the remaining systems revealed challenges in entering fictitious “test patients” to confirm that an issue identified locally or externally had been resolved. Some of our initial sessions attempting to “walk through” the CAT at the collaborating sites were hindered by difficulties properly entering test patients, particularly inpatients (i.e., how to “admit” a fictitious test patient, including the need to first provide his insurance status, DNR orders, etc.). This limited our ability to learn about and from some of the systems.

PROPRIETARY DATA ISSUES AND VENDOR PERMISSIONS TO SHARE SCREENSHOTS

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The refusal of one vendor to permit sharing of screen shots ran counter to both this FDA’s task order initial precondition as well as multiple high-level panels’ HIT safety recommendations.<sup>29</sup> It is hard to justify from a safety viewpoint why such permission was withheld, despite vendors’ proprietary concerns. Identifying, preventing, and learning from errors and improving prescribing safety should be a priority and should take precedence over commercial considerations (and to the extent correctable problems can be identified, likely would result in an improved commercial CPOE product). In cases where we sought to illustrate problems in this system, we drew generic screenshots to illustrate the issue in question.

## C. SPECIAL CPOEMS ERROR STUDIES

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From the data sources we reviewed, we undertook a number of special studies to better understand CPOE errors in general, as well as specific types of errors that appeared to be directly related to CPOE.

MEDICATIONS DISCONTINUED DUE TO “ERROR (ERRONEOUS ENTRY)”

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One particularly novel data source we identified and mined at BWH was data from medication discontinued with the reason providing by the clinician as “Error (Erroneous Entry)”. This was a previously untapped database which we found contained over 20,000 CPOE orders discontinued annually with error being the reason. Because of the FDA’s interest in drug name issues, we retrospectively focused on a series of “drug-pairs” in which an erroneous entry that was discontinued was followed shortly thereafter by an order for a new drug, suggesting that the drug name may have caused confusion (Appendix G). In each of these cases there was a strong suggestion that clinicians were confused about the drug name or product, which resulted in significant numbers of corrected orders (in many of these cases the initial listing was by a non-physician as part of the medication reconciliation step, as explained below).

We also manually reviewed the patients’ charts for these cases. However, we found no comments or notes explaining or even mentioning the error. Because clinicians never documented the error or the reason for the error, reasons could only be inferred from this retrospective study. This led our team to design and implement a prospective study in which we asked physicians entering these erroneous discontinuation orders in near real time via an email request to provide additional details. In this prospective study, a BWH programmer wrote an algorithm to send emails daily to prescribers who had discontinued medications during the previous 24 hours

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<sup>29</sup> Health Information Technology Patient Safety Action & Surveillance Plan for Public Comment. December 21, 2012. The Office of the National Coordinator for Health Information Technology.

indicating the reason “error (erroneous entry)” in the BWH outpatient LMR CPOE system. The email identified the patient and medication discontinued and requested that the prescribers provide information about **why they discontinued the particular drug** and checked off “error (erroneous entry)” for that particular patient. Data were collected over a four-month period (3/20/14 – 7/20/14). To avoid excessive burden on respondents, the program was designed to send a given prescriber only one email (i.e., they were excluded from all subsequent daily emails after receiving one such email). Of the 542 emails sent over the study period, we received 312 responses, yielding a remarkably high response rate of 58%. Our CPOEMS team reviewed each response and used a revised and adapted version of the BWH MedMarx Taxonomy to categorize “what happened to the patient” and “what happened in CPOE” (Appendix C).

From among the responses, the top categories of responses to “What happened to the patient?” were: wrong patient received drug, or nearly received drug; patient received or nearly received wrong drug; and patient received or nearly received a duplicate drug (same exact drug, or in same therapeutic class). The top categories of “What happened in CPOE” include: medication ordered for wrong patient; ordered wrong drug; and duplicate order (the majority of which were same exact drugs).

#### REVIEW OF “VOIDED” ORDERS

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At one site, medications discontinued due to error are called “void” orders, and a reason is required in order to proceed with the request to void the original order. Of the five million orders placed at this institution over a six year period, approximately 28,000 (<1%) were voided orders. The reasons that prescribers provided for voiding an order are summarized in Table 8 below. As in the BWH prospective study, “wrong patient” errors were among the leading reasons. Another category, “improperly composed order,” were voided prescription orders considered to be “good catches.” Both void order reasons have implications for CPOE safety and should be further investigated to better understand how they occur. Duplicate orders, the leading category, also are potentially reducible with better design and workflow, as are a number of other categories. Another set of void data from 2006-2011 was obtained from the inpatient, outpatient, ED, some procedure areas, and surgicenter of this site. Of the 5,320,998 orders were placed in this six year period, 28,401 orders were voided (0.5% of all orders). The BWH team divided the drugs into seven categories to investigate medication characteristics that might cause a larger void ratio. Withdrawn medications, obsolete medications, non-medication entries, ISMP commonly confused drugs, and OTC medications have void rates above the average medication void rate. The top ISMP commonly confused drugs that are voided include rifaximin, naloxone, sulfadiazine, quinine, hydrocodone. The top drugs voided overall were: NaCl, Nonformulary Medication, diphenhydramine, potassium chloride, and D.

**TABLE 4. VOID REASONS AT ONE SITE, SEPTEMBER 2002-JULY 2012.**

VOID REASONS	Number of prescriptions voided	% of void orders	% of total orders
Duplicate Order	23,581	79.0%	0.379%
<b>Wrong Patient</b>	<b>1,912</b>	<b>6.4%</b>	<b>0.031%</b>
Order on Wrong Encounter	1,459	4.9%	0.023%
Incorrect Ordering Physician	957	3.2%	0.015%
Voiding Student Order	815	2.7%	0.013%
System Date Error	599	2.0%	0.010%
<b>Improperly Composed Order</b>	<b>510</b>	<b>1.7%</b>	<b>0.008%</b>
All Voided Orders	29,834		

## ANALYSIS AND CLASSIFICATION OF PATIENT SAFETY REPORTS

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A more traditional but highly useful data source that we mined from all of the sites was patient safety reports. We examined error reports that had been coded as medication errors in the “ordering and prescribing phase” and investigated the role that CPOE may have played in the events described. Even when CPOE was not the direct cause, we assessed how better-designed CPOE systems might help prevent these errors. Although each of the collaborating organizations had formal safety reporting programs in place, none had previously undertaken this type of in-depth and broad review focusing on CPOE errors. We were able to review more than one thousand such reports using the BWH MedMarx taxonomy, which helped us glean both quantitative and qualitative insights about ways CPOE could be improved.

We identified and reviewed a total of 2,522 safety reports across the six sites in 2013 that were related to medications. Approximately 17% of the medication related adverse event reports were from the ordering and prescribing phase, while the other reports were from the administration, approval, transcription, monitoring, or dispensing phases. BWH team research assistants and pharmacists carefully reviewed the data:

- a. To determine whether the reported event appeared to be related to CPOE.
- b. To classify the general role of CPOE in the event:
  - i. CPOE facilitated the error; or
  - ii. CPOE failed to prevent the error.
- c. Using the BWH MedMarx Taxonomy codes for more granular classification of CPOE-related errors to describe both “what happened to the patient” and “what happened in CPOE.”

The ability to make these determinations was dependent on the amount of detail available. While we continue to iteratively refine these operational definitions and taxonomies (see Appendix C and D), the definitions applied in categorizing reports in this study were the following:

*CPOE facilitated (i.e., actively contributed to) the error.* Examples include:

1. system bugs contributing to error
2. computer malfunction
3. confusing screen layout
4. problem entering order, leading to problematic workaround (e.g., comments field)
5. interoperability-related problem
6. order entered on wrong patient
7. confusing or erroneous default settings (e.g., order sets, frequency, etc.)
8. pull-down menu or adjacency errors
9. failure of decision support available in the system
10. wrong quantity (auto-populate errors and failures)

*CPOE failed to prevent the error:* while CPOE did not actively contribute to the error, better-designed systems could have prevented the error. Examples include:

1. lack of CDS alerting by the system
2. a form that does not exist in the system and must be completed on paper, with the risk of confusion due to poor handwriting
3. prescription mailed to patient without physician signature
4. pharmacy unaware that medication has been discontinued

We found a great deal of variation in the quality, format, and accessibility of these reports. Reports from most of the sites were from the inpatient setting and written in narrative form by the frontline staff. Across the sites, 35.0% of the medication-related error reports from the ordering and prescribing phase we reviewed were classified by our CPOEMS team (pharmacy and clinician reviewers) as being related to CPOE issues; most of these were cases of CPOE failing to prevent the error (45.1% of all reviewed errors, 86.9% of CPOE-related reports),

suggesting opportunities for improved CDS. The majority of CPOE-related errors were related to dose (i.e., ordered wrong dose or strength).

#### DUPLICATE BRAND AND GENERIC DRUG ORDERING

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We extracted medication prescribing information for instances when the brand and generic forms of the same drug appeared simultaneously on a patient's active medication list at BWH from 2011-2013. Of the 1,175 extracted instances of brand/generic duplication in December 2013, 39 instances of the top 11 drugs most frequently appearing on charts as brand and generic forms were investigated by chart review. We hypothesized that most of the cases of brand/generic duplication are due to the physician ordering alternative doses or an unavailable dose. Some instances included one prescription by a physician and another medication reconciliation entry by a non-prescriber.

The drug that appeared most frequently in charts with concurrent duplicate entries with both brand and generic names was levothyroxine sodium. We found that patients often receive different doses of levothyroxine sodium on different days of the week. While it is possible to order variable doses in one CPOE order, many prescribers are unaware of the function or do not know how to use it. The active medication list in LMR was found to be confusing, as it contains both brand and generic names, includes some expired drugs that have not been renewed, and lists drugs that the patient is not necessarily actively taking as prescribed. Some prescribers may keep a drug on the active medication list to help them remember that the patient previously took that drug. Sometimes prescribers order two different doses of the same medication when their desired dose is not available. While most of the instances of the brand and generic drugs co-existing on a patient's active medication list appeared to be intentional—for the patient to have a more finely tuned regiment—this workaround of prescribing two orders of the same drug is a clue that this function should be better designed.

We recommend that there be a consistent way to group drugs so the brand and generic entries of the same drug appear adjacently in CPOE. Additional data on the reasons that prescribers are ordering the same medication more than once at the same time for a patient have been collected and are currently being reviewed for further insights.

## RECOMMENDATIONS

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Our findings highlight the need for better attention to CPOE design, workflow, and decision support as well as improvements in systems to more effectively identify problems and learn from user and system experience. Below we offer recommendations regarding CPOE systems themselves and their functionality. Then we suggest approaches for better oversight and monitoring of CPOE errors and problems, ways to more comprehensively identify and track problems, and organize and share issues within and across organizations. We also address issues of particular interest to the FDA such as drug name search and display, which could be made less error prone and embedded in a learning loop to identify and minimize CPOE-related and CPOE-preventable errors.

### A. IMPROVE COMMUNICATION BETWEEN PRESCRIBERS, EHRs, AND PHARMACIES

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1. **Design systems to more reliably communicate between pharmacies and EHRs.** Three major recurring issues related to communication between CPOE systems and pharmacies (particularly outpatient pharmacies) are: i) inability to write and transmit prescriptions electronically for all medications (e.g., controlled substances); ii) lack of systematic feedback on primary and secondary non-adherence, and most importantly; iii) lack of automatic transmission of drug discontinuation orders in CPOE to the pharmacy. To overcome these problems and related issues, we recommend:
  - a. Accelerate progress on creation of **secure but prescriber-friendly mechanisms for incorporating controlled substances** into CPOE ordering and electronic (as opposed to paper) systems. While this capability has been in the process of implementation for a number of years, it still does not exist in Massachusetts or the other states that are home to the rest of the systems in our project. CPOE systems should be linked to the national network of the Prescription Drug Monitoring Program (PDMP) to facilitate easy checking for controlled medication refill histories to both avoid patient prescription abuse as well as ease the burdens of compliance requirements (for physician to check before prescribing) on prescribing physicians.
  - b. **Build closed-loop systems** to allow prescribers to know and track when a medication has been received, filled, and picked up by the patient at the pharmacy, similar to the currently existing linkages with Surescripts data, which makes available calculated information (of medication possession ratios) on patients' adherence along with the medications.
  - c. **Establish and implement more clearly defined protocols, standards, and channels for communicating medication discontinuations to dispensing pharmacies.** This is a particularly critical vulnerability, as patients could receive a prescription from the pharmacy that the physician already discontinued in CPOE. Prescribers often do not realize that the pharmacy is unaware of the discontinuation. This is especially important when adherence programs remind patients to take medications that may have already been discontinued by the clinician.
  - d. **Implement clearer protocols for handling orders to "hold" inpatient medications.** Systems differed in how they implemented hold functionality and, more important, users often attempted to hold medications in ways that were unpredicted by system designers or the pharmacy. For example, most systems implemented a specific hold order, but providers would enter a general care order to not give a medications. This general

## RECOMMENDATIONS

care order was visible to the nurse, but not the pharmacist, and left the medication as to-be-administered on the MAR. The proper protocol for changing a dose (i.e. modifying an order vs. discontinuing one order and writing another) was also a source of confusion.

**3. Ensure prescribers know which free text fields are transmitted to the pharmacy.** Standards should be adopted for the structure, use, and accessibility of free-text fields to ensure consistent use, a correct understanding of their purpose, and how they flow to the pharmacy and the prescription label. Comments can represent a laudable effort by prescribers to enrich the communication to the pharmacy and—especially if placed on the label—the patient. However, it is not always clear how and by whom comments will be used. We found many examples of errors from conflicting directions in free text vs. structured aspects of the CPOE order. Retrospective examination of free-text fields can be useful to identify and analyze comments, which are often markers for workarounds and other potential system design flaws.

## B. IMPROVE CPOE SYSTEM DESIGN AND FUNCTIONALITY

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By virtue of their disparate origins (commercial vendors or in-house development) and being effectively created in a vacuum, free of outside influences, the CPOE systems we studied differed from each other in myriad ways that led to user frustration and errors. Our findings support the need for more attention to consistent, standardized system design that will facilitate multiple domains essential for safer prescribing.

**1. Design CPOE search functions to be more intuitive and useful,** with results better organized, filtered, and prioritized. Engineers deeply experienced in human factors, human-computer interaction, and user experience should carefully incorporate principles of intuitive design, working to conform drug searches to what can be learned about the mental model of the user. If prescribers cannot easily locate a medication they are attempting to order, the system is not well designed. The goal should be to make it easy for prescribers to find a medication they are seeking to order, but not overwhelm them with a plethora of irrelevant, confusing, or potentially erroneous “neighboring” choices. Problems such as users being unaware of the various ways that drugs are listed and searchable in their systems need to be identified or examined through watching users, as we did using the CAT and other simulations. Tensions between formulary constraints and comprehensive unfiltered lists of all available products (from knowledge vendors) need to be confronted.

### 2. Drug Display

- a. **Drug name displays should be made consistent both within and across systems and sites** (common disparities included brand vs. generic, and even inpatient vs. outpatient at the same site). While pharmaceutical companies enjoy the advantages a brand product name can provide, prescribers, pharmacists, and patients continue to struggle to keep these two (or more) names for a drug straight. Electronic medication ordering systems ideally could be helpful for mapping and then facilitating search and display and organization of drugs despite brand and generic name assignments. While without more rigorous testing we hesitate to offer a best practice here (as with a number of our recommendations), simplicity and consistency are two well-validated design principles that should guide more standardized approaches within and across systems. Because multiple educational and pharmacy practice organizations recommend using the nonproprietary generic name, systems should be consistently designed to embrace this, especially as it may reduce costs. Thus generic name, with brand in parenthesis, would be a logical standard. In addition, there needs to be careful consideration of how to best use and display combination products to avoid confusion and lack of standardization.

## RECOMMENDATIONS

- b. **Suffixes and other modifiers of drug names should be displayed in a standard way.** Modifiers appear primarily at the end of the drug name, but cause confusion when their meanings are unclear. CPOE systems should assist prescribers in understanding the differences, e.g., sustained release (SR) vs. extended release (XL). Positive steps to decrease confusion could begin with directing prescribers to the preferred formulation, to info buttons or explanation information immediately available by holding the cursor over the suffix/modifier, and encouraging the FDA and industry to simplify these categories and nomenclature. Our retrospective study of erroneous prescriptions pointed to frequently confused drug products and pairs suggesting a number of specific products (e.g., Vitamin D) where additional efforts along these lines might be directed.

We were intrigued by efforts to include drug indication and other related modifiers in the drug name itself (e.g., Methotrexate – Rheumatoid Arthritis vs. Methotrexate – Oncology). However, creating these non-standardized names signaled a workaround for other shortcomings (lack of indication-based ordering, problem-prone regimen confusion) that could perhaps be addressed in better ways than ad hoc tampering with drug names.

3. **Incorporate safeguards against wrong-patient errors.** Wrong-patient errors were the most frequent type of error we identified in our erroneous CPOE orders prospective study. The ease with which the wrong patient’s chart can be accessed in CPOE and the ability to have several patients’ records open simultaneously create vulnerability to error, which could be made less likely, for example, by implementing visual cues (pictures, more prominent display of patient names) to ensure prescribers know for which patient they are entering, placing indications on the prescription as an error check (“I don’t have gout”), or perhaps limiting the numbers of charts that can be opened simultaneously. So called “pull-down” wrong-patient selection errors could be minimized by other features in screen and workflow design (e.g., initial list limited to provider’s own patients, spacing between line items).

## C. IMPROVE SYSTEMS FOR IDENTIFYING, UNDERSTANDING, TRACKING, AND LEARNING FROM CPOE ERRORS AND PROBLEMS

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We found many “hidden” errors and glitches with a concomitant under appreciation of the extent and impact of the known types of CPOE errors. There is a need for better systems to uncover, understand, and learn from such errors.

### 1. Create an enhanced local reporting system to gather CPOE-related errors and opportunities for improvement from multiple sources

- a. From end-users at hospitals and practices, formally collect CPOE problems and error information (including near misses) in real time and apply root-cause analyses.
- b. Support easy, convenient reporting of CPOE issues. One suggestion is to provide a single "button" (or an equivalent means of rapid communication) to capture a screen shot that would allow any clinical user to quickly send a context-specific report on any CPOE element found to be confusing or frustrating—often with the potential to cause error. We identified numerous examples in which user confusion and frustration translated into potential for errors—particularly via resorting to workarounds (e.g. using comments fields) or reflexively overriding alerts.
- c. Create a means of standardizing user feedback reports, which we define as feedback on the system short of an error report, e.g., calls to the help desk, requests for a specific feature, or complaints. Standardized information would help to identify specific CPOE features and functionality issues to address.

### 2. Investigate reports thoroughly to understand root causes; take corrective action

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a. Users often felt that their error reports went down a “black hole” and were never acted on. Ensuring that robust systems are in place to review, investigate and act on reports and communicate results is important, both to maximize improvements for a given report, as well as to encourage future reporting.

### 3. Install proactive surveillance systems to monitor various markers of potential errors

Surveillance systems should be put in place to proactively monitor various markers of potential errors.

One particular surveillance screen—drug discontinuations where the reason is indicated as related to CPOE system design—should be built into systems and regularly monitored and tracked.

4. **Re-engineer pharmacy intervention logs to ensure capture of CPOE shortcomings.** Pharmacists often intervene on orders to ask for clarification or to convey issues with a prescription, some of which may be caused by CPOE issues. Logs of these interventions should be re-engineered to ensure they are maximally informative. They should both follow a standardized structure (perhaps modeled after SBAR [Situation, Background, Assessment, Recommendation] structured communication protocols<sup>30</sup>) and be coded to facilitate organization and maximal learning towards the improvement of the CPOE system.

5. **Collate, organize, code, and standardize error data in a central repository,** which we believe will make learning much more efficient as well as yield more usable evidence-based findings for application in other systems. We suggest it be organized according to a common **taxonomy** describing:

- a. the types of errors discovered and the reasons behind them. The Agency for Healthcare Research & Quality (AHRQ) Common Format<sup>31</sup> should be further evaluated to determine its utility in facilitating error classification.
- b. the phase of medication use during which each reported error occurs, in order to facilitate trends and identification of recurrent or systematic issues.
- c. any potential contribution of the CPOE system to the error; that connection could be made either by the end user herself or an IT staff member addressing the error. The taxonomy developed by the CPOEMS team should be further refined and deployed for both research and institutional use in classifying CPOE-related errors.

6. **"Close the loop" with users who submit reports to empower them to continue their participation.**

## D. ENHANCE LEARNING SYSTEMS

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1. **Provide CPOE users with real-time support, and learn from user experience and frustrations.** Real-time “help desk” support would help users avoid mistakes and workarounds they may be considering. Users should feel empowered to speak up about concerns and act on their commitment to help improve the system. Such real-time support also helps the organization continuously hear about and learn from problems at the front lines, which can be extremely valuable, particularly if there is ongoing monitoring and analysis of concerns that are being identified via this and other channels.

2. **Improve two-way communication with/learning from pharmacies, especially including medication discontinuation orders** (discussed more fully in “Improve Communication between Prescribers, EHRs, and Pharmacies,” above).

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<sup>30</sup> Trentham, B., Andreoli, A., Boaro, N., Velji, K. & Fancott, C.(2007). SBAR: A Shared Structure for Team Communication. Toronto Rehabilitation Institute: Toronto.

<sup>31</sup> Patient Safety Organization Program: Common Formats. (2014). Retrieved from <https://www.pso.ahrq.gov/common>

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### 3. Share errors among institutions to promote corrective action

- a. Systems for sharing errors among local institutions and vendors should be improved to increase error awareness and promote corrective action.
- b. Hospitals should be encouraged to formally monitor errors occurring in other institutions (both those using the same vendor system and more generic problems) reported in the literature and from sources such as ISMP. To maximize the utility of such “environmental scanning,” institutions should evaluate whether their systems are vulnerable to similar errors (similar to what some institutions do to monitor ISMP safety reports) through review and testing.
- c. National systems should be employed to increase awareness of the types of errors and vulnerabilities.
  - i. Error-reporting systems should be made nationally interoperable to benefit all sites. Disparate systems should be reconciled to help ensure desired interoperability and transparency.
  - ii. Issues or errors could be disseminated through existing mechanisms, including FDA channels, e.g., Adverse Event Reporting System (FAERS), Manufacturer and User Facility Device Experience (MAUDE), the proposed Office of the National Coordinator for Health Information Technology (ONC) reporting system, and the Emergency Care Research Institute (ECRI) Partnership for Promoting HIT Patient Safety, and Institute for Safe Medical Practices (ISMP).

### 4. Require vendors to share screenshots and error reports

- a. Vendors should be required to permit the sharing of screenshots and information with the FDA and other institutions regarding other CPOE system issues of concern or that pose risk for errors.
- b. The practice of prohibiting such sharing via copyright must be eliminated.
- c. Vendors should be required to disclose errors reported to them or errors identified in their products, analogous to the requirement that drug manufacturers report significant adverse drug effects.

### 5. Recognize that many providers are working with multiple ordering systems

a. Many providers, particularly trainees, use multiple systems, each with different interfaces, drug dictionaries and procedures. Where possible, standardization of approaches may be useful to minimize the cognitive burden and workflow challenges for users of multiple systems.

### 6. Implement systems for testing vulnerabilities to reported errors

- a. Systems should be tested for vulnerabilities before errors occur, using tools/models such as Safety Assurance Factors for EHR Resilience (SAFER), EHR safety evaluation test administered by Leapfrog, and the BWH MedMarx test scenarios (see Appendix E).
- b. System effectiveness should be tracked, as assessed by the number of clicks required to complete a particular drug order, and whether some user-outliers are taking many more clicks than others to order a drug.
- c. The process of creating fictitious “test patients,” either to probe issues identified locally or externally or to confirm that an issue has been resolved, should be simplified. “Admitting” a test inpatient or “registering” a test outpatient must be straightforward for IT personnel and any clinical personnel assisting in system improvement.

## E. IMPROVE CONSISTENCY AND RELIABILITY OF CLINICAL DECISION SUPPORT

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The consistency and reliability of CDS must be greatly improved within and across systems and sites. We found that this crucial feature of CPOE systems varied by drugs, how drugs were accessed, the setting (inpatient vs. outpatient), the user's role (e.g., physician vs. medical assistant), and content. For example, an alert fired when the user ordered a drug by its brand name but not when it was ordered by the generic name.

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**1. Better integrate CDS into workflow (including "5 Rights"<sup>32</sup> and "10 Commandments"<sup>33</sup>).** For CDS to maximally assist the prescriber—by providing information exactly when the prescriber needs help—system designers need to better understand prescribers' workflow. For example:

- a. Use defaults and system-calculated suggestions (e.g., renal dosing) as much as possible rather than "after-the-fact" alerts, which slow workflow and are often ignored.
- b. Use forcing functions (such as hard stops) to prevent the most serious errors.
- c. Use alternative methods (e.g., requiring entering reasons, informational screens) to prevent less-serious errors, seeking always to minimize nuisance and disruption of workflow.

**2. Track overrides for alert type, rates, reasons, drugs involved, appropriateness, user demographics, and geographic unit to learn from alert and physician behavior to further refine the utility of alerts.**

**3. Establish automated proactive surveillance to monitor alert behavior**

Structured data about alert rates and override reasons should be made available in a timely manner and be practically usable by CPOE systems to create queries and generate override reports:

- A. detect any aberrant behavior of the alerts (e.g., an alert unexpectedly stops firing after system upgrade)
- B. eliminate harmful overriding of critical and appropriate-for-patient alerts
- C. track what is learned and changed from monitoring override rates and CDS alerts across other sites and systems.

**5. Offer patient-specific drug and dosing suggestions**

- a. Patient-specific drug and dosing suggestions (such as Nephros and Gerios programs developed and in place at BWH<sup>34</sup> and less well-developed versions in commercial systems) based on patient age or renal function should provide the default for dosing in CPOE orders. These are preferable to "after-the-fact" warnings, which are often ignored.
- b. Drug quantity and duration: We observed frequent use of "order sentences" that included duration and quantity, pointing to the need and desire of prescribers to have this type of helpful prescribing support. However, such order sentences can be vulnerable to other problems such as not triggering warnings regarding drug duplication or dosing limit, and other warnings not being triggered by free-text sentences. There needs to be attention to these issues to test and correct such vulnerabilities.
- c. Proper "matching" of route and other instructions with drug being prescribed, as found in order sentences. Greater attention to ensure correct and more limited context-specific choices; for example asthma sprays should not be able to be given per IV.

In summary, based on our research and extensive interactions with systems users, the BWH CPOEMS team envisions moving CPOE from a vendor/customer model to a more open and collaborative paradigm:

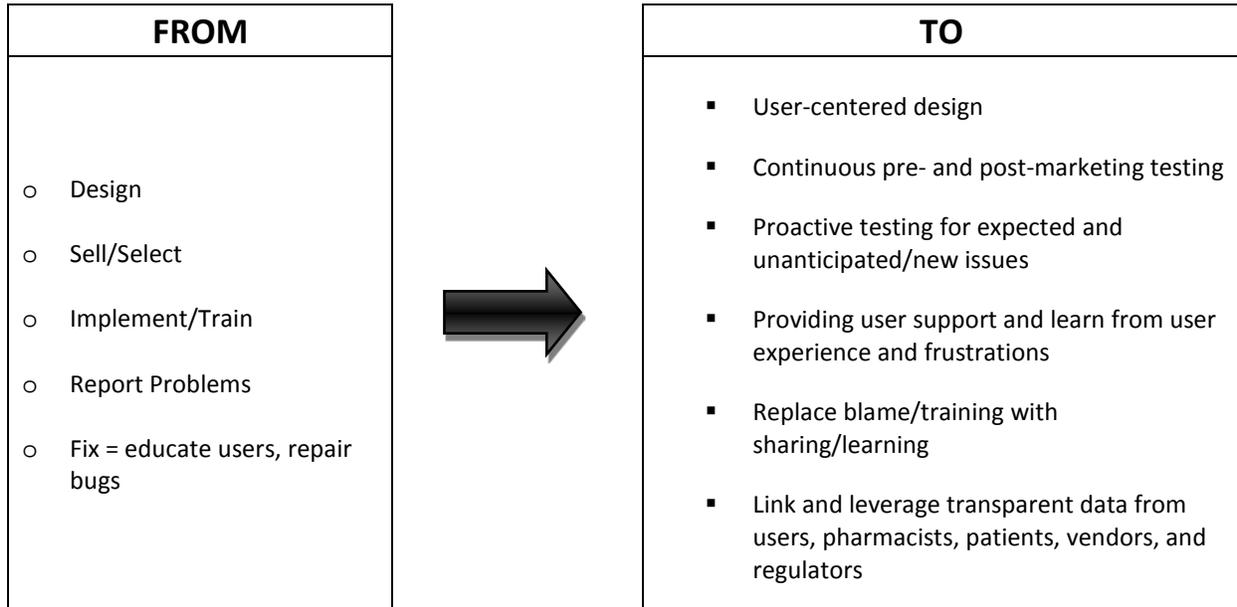
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<sup>32</sup> Campbell R. The Five Rights of Clinical Decision Support: CDS Tools Helpful for Meeting Meaningful Use." Journal of AHIMA, 2013; 10:42-47.

<sup>33</sup> Bates DW, Kuperman GJ, Wang S, Gandhi T, Kittler A, Volk L, Spurr C, Khorasani R, Tanasijevic M, Middleton B. Ten Commandments for Effective Clinical Decision Support: Making the Practice of Evidence-based Medicine a Reality. JAMIA, 2003;10:523-530.

<sup>34</sup> Chertow GM, Lee JL, Kuperman GJ, Burdick E, Jorsky J, Seger DL, Mekala A, Song J, Komaroff AL, Bates DW. Guided Medication Dosing for Inpatients With Renal Insufficiency. JAMA. 2001; 286: 2839-2844.

## RECOMMENDATIONS



## APPENDIX A: ABBREVIATIONS

AHRQ	Agency for Healthcare Research & Quality
BICS	Brigham Integrated Computing System (BWH inpatient system)
BWH	Brigham and Women's Hospital
CAT	CPOEMS Assessment Tool
CDS	clinical decision support
CMS	Centers for Medicare and Medicaid Services
CPC	Clinical Prioritization Committee
CPOE	Computerized Prescriber Order Entry
CPOEMS	Computerized Prescriber Order Entry Medication Safety
DAI	drug allergy interaction
DDI	drug-drug interaction
DEA	Drug Enforcement Administration
DMEPA	Division of Medication Error Prevention and Analysis
DS	double strength
ECRI	Emergency Care Research Institute
EHR	electronic health record
FAERS	FDA Adverse Event Reporting System
FDA	Food and Drug Administration
GE	General Electric
HFA	hydrofluoroalkane
HIT	health information technology
HUP	Hospital of University of Pennsylvania
HVMA	Harvard Vanguard Medical Associates
INJ	injection
INR	International Normalized Ratio
IOM	Institute of Medicine
IRB	Institutional Review Board
ISMP	Institute for Safe Medical Practices
IT	information technology
KPNW	Kaiser Permanente, Northwest
LASA	Look-alike/sound-alike
LMR	Longitudinal Medical Record (BWH outpatient system)
MA	Medical assistant
MAUDE	Manufacturer and User Facility Devise Experience
MMC	Montefiore Medical Center
MSRC	Medication Safety Research Committee (at one site)
NICU	Neonatal Intensive Care Unit

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NPH	Neutral protamine Hagedorn (insulin)
OE	order entry
ONC	<b>Office of the National Coordinator</b> for Health Information Technology
PAML	Pre-admission Medication List
PCP	primary care physician
RCA	root cause analysis
RL Solutions	Radiologic Solutions
Sound alike look alike	SALA
SAFER	Safety Assurance Factors for EHR Resilience
SS	single strength
SR	sustained release
TCS	Team Coordination System
TPN	total parenteral nutrition
UIC	University of Illinois-Chicago (Hospital and Health Science System)
UPHS	University of Pennsylvania Health Sciences System
XL	extended release

## APPENDIX B: CPOE ASSESSMENT TOOL (CAT)

### System Characteristics Guide

#### I. General Assessment Overview

The FDA Computerized Prescriber Order Entry Medication Safety (CPOEMS) project involves an assessment of inpatient and outpatient clinical information systems at participating sites to better understand the role of CPOE in preventing, and potentially introducing medication errors.

This guide sets out standardized procedures to facilitate comparative analyses across the sites. These protocols are intended as a general guide to examine the ten systems in a standardized and comparable fashion. However because investigators, test subjects, and system characteristics vary across sites, assessment processes may be altered, as necessary to maximize the learning and efficiency of the testing activities. The goal will be to document and understand how the varying CPOES displays and processes look and work, as well as examine the vulnerabilities of these systems to potential prescribing errors. We will emphasize collecting of information of interest based on the to the FDA 18 elements of interest, utilizing a combination of screen shot review, remote interactive sessions, and onsite review to be followed up with interviews of CPOE HIT leaders and developers at each site.

#### *Screenshots Review*

The centerpiece of the screenshot review exercise will be a walkthrough of selected CPOE ordering features with regular users of the system (i.e. not the developers or IT experts). Prior to this formal review, we will conduct interactive examination of screenshots with each of the local investigators to allow us to familiarize ourselves with the basic look of the site-specific system and to collect data on some of the elements that a user or even IT expert may not know about such as font size of the text, etc.

#### *Live Interactive Sessions*

The remote interactive sessions with regular users at each of the sites will be conducted through the use of *WebEx* as a webinar tool along with *SnagIt* and *Camtasia* to capture screenshots. These session tools will be hosted by local site investigators and led and conducted by the BWH team. There will be 2-3 BWH staff involved in each walk-through to: (1) ask questions and interact with the user; (2) collect screen shots representative of medication ordering scenarios, and to ask clarifying questions; and (3) take typed notes. In addition, the sessions will be recorded.

#### *Onsite Visits*

Once screenshots have been reviewed and live interactive sessions held with a number of the roles at each site, an assessment will be made of the outstanding areas and questions that are important to cover in an in-person meeting with site coordinators and staff. As mentioned, this approach will allow for more in-depth exploration of critical findings during the site visits.

The overarching focus of this evaluation will be on order entry systems with clinicians as the end user. There are multiple entry points for a medication to enter a patient's EHR; however, the focus of this assessment will be on the inpatient and outpatient medication order entry EHR systems. Therefore, we will be excluding medication reconciliation applications, laboratory ordering systems, and other ancillary systems that could be used for entering orders (besides medications) or those that do not have the physician as the end user (e.g. pharmacy order entry systems). CPOE system and related EMR medication displays for the inpatient and outpatient settings will be reviewed.

The following pages of this guide present general system overview questions and the specific medication ordering scenarios that users will enter into their systems to elicit the system characteristics of interest in this study.

## **II. General Overview of Your CPOE System**

1. Please describe the following characteristics of your system for both outpatient and inpatient systems:
  - a. History
    - i. Length of time system has been implemented at your institution
    - ii. Is your EHR commercial-off-the shelf or created by your institution?
    - iii. Is your medication knowledge base commercial-off-the shelf or created by your institution (such as a proprietary medication dictionary)?
  - b. How can the system be accessed (e.g., kiosks, iPads, desktop only)?
  - c. Who is capable of entering orders in the system? Do the ordering capabilities and CDS features vary by role?
2. Please walk us through the components of your system to help us understand the process of entering a new prescription—completing the process of entering a medication order

(Note to interviewer: All the different screens associated with ordering a medication through the different processes will be named and recorded by the interviewer)

## **III. Assessment of 18 System Characteristics**

1. **Fonts Used** (type, size, serif/sans serif): captured but **does not need to be specifically evaluated during the interview**

- a. Task 1: *Patient Chart Summary Screen*  
Enter test patient and retrieve patient chart summary screen
- b. Task 2: *Medication Summary Screen*  
Enter test patient and retrieve medication summary screen.
- c. Task 3: *Ordering New Prescription*
- d. Task 4: *Reactivating Previous Prescription*  
[How is this information retrieved for viewing?]
- e. Task 5: *Patient Medication/Allergy List Screen*  
Enter test patient and retrieve medication/allergy list screen
- f. Task 6: *Medication Alert: Drug- Drug Interaction* [will be multiple ones]  
[How is this information retrieved for viewing?]

Patient medication lists  
Other drug summary list

## 2. **Drug Name Types**

Drug names may be listed in CPOE databases by generic name, proprietary name, or both.

*Questions for the interviewer to consider:*

- *Which med name(s) (brand/generic) appear in the search results?*
- *Which med name(s) appear in the general search results under favorites?*

a. Task 1: *Generic name/Proprietary Name*

Example 1

1. Enter “lovastatin” into the medication ordering search field and complete the order -- should generate drug pregnancy alert (**previously entered ‘pregnancy’ in the problem list**)

Example 2

2. Enter “plavix” into the medication ordering search field and complete the order

Example 3

3. Enter “warfarin” into the medication ordering search field and complete the order

Example 4

4. Please enter ‘amytriptiline’ and complete the drug order (**example of misspelling**)

**3. Drug Name Presentation (Does not need to be evaluated during the interview)**

Drug names are presented in various ways in CPOE databases (e.g. capital or mixed case letters) and may differ based on generic or proprietary name and individual screen display.

*Questions for the interviewer to consider:*

- How are drug names added to the medication list in your system? By generic name, proprietary name, either, or both? [*may differ based on different screen display*]
- How do the drug names appear? (e.g. in capital or mixed case lettering?)

**4. Presentation of Combination Products**

The presentation of names of combination products varies in CPOE systems.

*Questions for the interviewer to consider:*

- When a drug name is searched, do the search results display all of the options that include that drug name as an ingredient or only that drug?
- In what order are the ingredients placed?
- Are the strengths for the ingredients listed separately?

a. Task 1: *Drug made of combination products*

1. Enter “Bactrim” into the med ordering field and choose “Morphine sulfate and naltrexone extended-release capsules in the 60mg/2.4mg combination”
  - i. *This is an example of both a combination product and one with extended release characteristics by type of release.*
  - ii. *Note how strengths of ingredients are listed*

b. Task 2: *Drug that constitutes a combination product*

1. Enter “hydrochlorthiazide” into the medication ordering search field and choose a HCTZ/Lisinopril combination such as “Prinzide or Zestoretic”.
2. Can you do an automated sig selection choosing the default dose?
3. Does this generate an alert for drug lab (**potassium is too high: set at 8.0meq/L**)

c. Enter Sinemet (Carbidopa/Levodopa) combination and complete the order.

**5. Drug Names with Modifiers**

How are modifiers of drug names presented in your CPOE system?

*Questions for the interviewer to consider:*

- *Are the modifiers in all caps?*
- *Are they ever cut off by the text box or character limit?*
- *Where are they located in the string; ahead of the drug name, following it?*
- *Is there ever text spelling out the modifier or only abbreviations?*

- a. Task 1: *Type of Release* (extended release, sustained release, etc)
- b. Task 2: *Route of administration*
  1. Enter “fentanyl” into the med ordering screen
    - a. Note whether system distinguishes between the transdermal patch and the sublingual spray. Should be able to see different formulations of fentanyl, e.g.
      - Abstral™ (FENTANYL SUBLINGUAL TABLET)
      - Actiq™ (FENTANYL TRANSMUCOSAL LOZENGE)
      - Fentora™ (FENTANYL BUCCAL TABLET)
      - Lazanda™ (FENTANYL NASAL SPRAY)
      - Onsolis™ (FENTANYL BUCCAL SOLUBLE FILM)
      - Subsys™ (FENTANYL SUBLINGUAL SPRAY)
    - b. Please select Subsys, the sublingual spray, for breakthrough cancer pain, in an opioid-tolerant patients: how will you enter the following order:
      - i. 100 mcg under the tongue; may repeat once after 30 minutes; do not use more than 2 doses per episode of breakthrough pain; repeated treatment of subsequent episode should be separated by at least 4 hours; if adequate pain relief is achieved, use this dose for subsequent episodes of breakthrough pain.
- c. Task 3: *Salt name*
  1. Enter “ferrous” into the medication ordering search field and generate the search results.
  2. How does the system distinguish between ferrous sulfate, succinate, gluconate, lactate? May have to ask user to enter these terms separately or will be visible from search results.
  3. Choose ferrous sulfate
- d. Task 4: *Formulation* (liquid, powder, capsule, etc)  
See above for fentanyl example

## 6. Automated Selection of Drugs

Describe auto-fill for drug names and sigs [need full range of how drug names AND sigs can be selected. Determine with site coordinator beforehand whether there is anywhere in the system where putting in the first 3 letters will auto-fill the med name]

*Questions for the interviewer to consider:*

- *If a drug name appears in the favorites list does it also appear in the regular medication selection list or is it removed from regular list when it appears in favorites?*
- *Are the options presented in alphabetical order?*

- a. See 5b for Prinzide example for auto SIG.

## 7. Short Code Capability

What is your system's short code capability? How are they developed and, if they are listed in a particular order, why was this order selected?

*Questions for the interviewer to consider:*

- Does this system search only from the stem?
- Search only from the beginning of the word, or inside the drug name
- Filter more selectively as you add letters?
- Present different results for different scenarios (search vs. quick order, etc)
- Present results in which the words all run together or are parsed out
- Present drugs that appear consistently across results (gets at oddities—how is the system searching if not simply from the medication column?)
- Accept impossible drug names and allow you to enter orders from them

### a. Example 1

1. Order amoxicillin 500mg by entering “amox 500” into the medication ordering search field and generate the search results. Please enter the order for amoxicillin 500mg PO, q12h.
2. You have previously entered that the patient is really impaired and CrCl is 5.0.
3. Does this generate a nephros dose adjustment alert?
4. Does it provide value of CrCl or do you have to look it up? (CrCl is previously set at 5.0 ml/min)
5. Does the system provide suggested new dose? (should be 250 - 875 mg PO q24h for CrCl < 10 ml/min)

## 8. Indication of Spaces

How are spaces indicated on your CPOE screen (e.g. all words run together, spaces appear as actual breaks in name, or other?)

*Questions for the interviewer to consider:*

- Are '+' symbols ever used in lieu of spaces?
- Is there consistency across screen elements?

### a. Task 1

Example 1 – Long drug name with special characters

1. Enter “Chlorhexidine mouthwash 0.12%” into the medication ordering search field and generate the search results

## 9. Navigation Method

How do practitioners navigate the CPOE system? Indicate all that apply. [\[This information could be collected prior to interview\]](#)

*Questions for the interviewer to consider:*

- *Is more than one method possible?*
- *Does it differ across different CPOE elements within the system?*
- *Does it differ based on tool used to access CPOE (e.g. ipad)?*

- Mouse
- Arrow Key
- Touch Screen
- Wand
- Macros [\(could this differ within the system\)](#)
- Other

## 10. Drug Presentation Limitations

Limitations on drug name presentation include maximum character limitations, minimum characters for medication search, and limitations on the number of medications displayed. To elicit these different characteristics, please complete the following tasks.

*Questions for the interviewer to consider:*

- *If the box in which the med name is small enough that it hides parts of the drug name, is it possible to make it larger and/or is it possible to hover over the text until the full drug name appear?*
- *Does the search display as a drop down list, list of meds, a favorites list, etc?*
- 

Please search for the following drug names:

- a. methylprednisolone sodium succinate

Repeat the action of searching for the med in the following screens:

1. *Patient Chart Summary Screen Medication List*
  2. *Task 2: Main Medication List Summary Screen*
  3. *Task 3: Medication List – Favorites*
- b. This item tests minimum # of characters needed to look for a medication concept:
1. Enter “klo” in medication ordering search field and display list of meds
  2. Enter “clo” in medication ordering search field and display list of meds

## 11. Common Alerts Used

Describe any common alerts used consistently in the system (duplicate therapy alert, wrong dose/route alert). [\[Can site coordinators let us know how many levels of alerts are in their system prior to the interview?\]](#)

*Questions for the interviewer to consider:*

- *What are the types of alerts that are used? Are there tiers?*
- *In what contexts do they appear?*
- *How are each type displayed on the screen?*

- a. Task 1: *Duplicate Therapy alert*
1. Example 1 - Same Drug
    - i. You have already ordered **plavix** for this patient
    - ii. Order “**clopidogrel**” into the medication ordering search field and generate the search results
    - iii. Selected clopidogrel [specify exact drug selection]
    - iv. What appears on the following screen?
    - v. Please cancel the order for plavix and continue with the order for clopidogrel
  2. Example 2 - Drug class
    - i. You have ordered **lovastatin** for this patient.
    - ii. Order “**atorvastatin**” into the medication ordering search field and generate the search results
    - iii. What appears on the following screen?
    - iv. Please cancel the order for atorvastatin and keep the order for lovastatin
- [\[The following examples were generated based on BWH’s LMR alert scheme\]](#)
- b. Task 2: *Drug-Drug Interactions alert*
1. Example 1 - Level 1: [HMG Co-A reductase inhibitors-Protease Inhibitors](#)
    - i. You have already ordered **lovastatin**
    - ii. Now order “**indinavir**”
    - iii. What appears on the following screen?
    - iv. Can you override the alert and order both medications?
    - v. What reasons can you provide?
    - vi. Is there a free text field to provide additional comments for overriding the alert?
  2. Example 2 - Level 2: WARFARIN & LEVOFloxacin
    - i. You have already ordered **warfarin**.
    - ii. Now order “**levofloxacin**”.
    - iii. What appears on the following screen?
    - iv. Can you override the alert and order both medications?
    - v. What reasons can you provide?
    - vi. Is there a free text field to provide additional comments for overriding the alert?
  3. Example 3 - Level 3: warfarin + levothyroxine
    - i. You have previously ordered **warfarin** for this patient
    - ii. Now order **levothyroxine**
    - iii. What appears on the following screen?
    - iv. Can you override the alert and order both medications?
    - v. What reasons can you provide?
    - vi. Is there a free text field to provide additional comments for overriding the alert?
- c. Task 3: *Drug-Allergy Interactions*
1. Example 1 - Level 1 (DEFINITE allergy): single ingredient drug with single ingredient med: AMOXICILLIN with AMOXIL (or any other trade name of amoxicillin available in formulary)
    - i. You have previously ordered amoxicillin for this patient
    - ii. Please order amoxil.
    - iii. What appears on the following screen?
    - iv. Can you override the alert and order both medications?
    - v. What reasons can you provide?

- vi. Is there a free text field to provide additional comments for overriding the alert?
2. Example 2 - Level 2 (PROBABLE Allergy):
    - i. You have previously ordered amoxicillin for this patient
    - ii. Please order ampicillin (Omnipen, Principen)
    - iii. What appears on the following screen?
    - iv. Can you override the alert and order both medications?
    - v. What reasons can you provide?
    - vi. Is there a free text field to provide additional comments for overriding the alert?
  3. Example 3 - Level 2 (PROBABLE Allergy): single ingredient drug with multi ingredient med
    - i. You have previously ordered amoxicillin for this patient
    - ii. Please order augmentin (amoxicillin/clavulanic acid)
    - iii. What appears on the following screen?
    - iv. Can you override the alert and order both medications?
    - v. What reasons can you provide?
    - vi. Is there a free text field to provide additional comments for overriding the alert?
  4. Example 4 - Level 3 (possible Allergy): cross sensitivity
    - i. You have previously ordered amoxicillin for this patient
    - ii. Please order Keflex
    - iii. What appears on the following screen?
    - iv. Can you override the alert and order both medications?
    - v. What reasons can you provide?
    - vi. Is there a free text field to provide additional comments for overriding the alert?
- d. Task 4: *Drug Formulary Alert*
1. Example 1 - A drug not on the formulary
    - i. E.g. “**zyprexa**” into the medication ordering screen
    - ii. What appears on the following screen?
  2. Example 2 - A drug for which a lower priced alternative is available
    - i. Enter “**Cialis**” into the medication ordering search screen
    - ii. What appears on the following screen?
- e. Task 5: *Drug Inactive*
1. Example
    - i. You have previously order lovastatin
    - ii. Please Inactivate this order
    - iii. Now order it again –does the system alert you that this drug has been inactivated and enable activating a previously entered instance of the drug?
- f. Task 6: *Drug pregnancy contraindication*  
**Ordering atorvastatin for this patient should generate a drug pregnancy alert**
- g. Task 7: *Drug Dose Alert*
1. Example
    - i. Change the dose of lovastatin to 800 mg (max dose is 80 mg).
    - ii. What appears on the following screen?
    - iii. Can you override the alert and order both medications?
    - iv. What reasons can you provide?

- v. Is there a free text field to provide additional comments for overriding the alert?

**12. Processing Telephonic and Verbal Orders**

- a. Please describe the *actual* methods used for processing of telephone and verbal orders and *workarounds* that may also be used across users.
- b. Collect copy of institutional Policy and Procedures relating to processing these types of orders.  
 Requested     Received  
PolicyTitle: \_\_\_\_\_  
Last Reviewed Date: \_\_\_\_\_

**13. Discontinuation of meds:**

- a. How do you discontinue a med?
- b. What happens when you do that? (screenshots)
- c. What is the result? (where does it appear and what do they think happens to the information)

**14. Drop-down Menus**

How do drop down menus appear in your CPOE system given a particular view (e.g. single drug list or multiple drug list view)? Do drop down menus exist for searching a drug? For which of the following medication components do drop down menus exist in your system?

- Drug Name
- Med Attributes
- Dose
- Frequency
- Pre-formulated SIGs
- Strength and Form
- Formulation

**15. Summary Comments/Observations**

Medication summary screen  
Inactivate a medication and then reactivate it  
Can you generate a patient handout/prescription for the drugs that we ordered?  
How has the system evolved—change log  
Process for communicating the changes to vendors.

## APPENDIX C: REVISED MEDMARX TAXONOMY

### WHAT HAPPENED TO THE PATIENT (P)

#### Patient (p)

Pp1. Wrong patient received drug, or nearly received drug

#### Drug (d)

- Pd1. Patient did not or nearly did not receive medication
- Pd2. Patient received or nearly received wrong drug
- Pd3. Patient received or nearly received wrong dosage form or formulation of correct drug
- Pd4. Patient received or nearly received drug to which s/he was allergic
- Pd5. Patient received or nearly received drug that was inappropriate or contraindicated
- Pd6. Patient received or nearly received a duplicate (same exact drug, or in same therapeutic class)

#### Dose (do)

- Pdo1. Patient missed or nearly missed dose
- Pdo2. Patient received or nearly received extra dose
- Pdo3. Patient received or nearly received wrong dose
  - a. Dose higher than indicated or appropriate
  - b. Dose lower than indicated or appropriate

#### Route (r)

- Pr1. Patient received or nearly received medication via wrong route
- Pr2. Patient received or nearly received medication in wrong side of the body (R vs. L mixed up)

#### Time (t)

- Pt1. Delay in medication being given or dispensed

### WHAT HAPPENED IN CPOE (C)

#### Patient (p)

- Cp1. Medication ordered for wrong patient
- Cp2. Medication ordered on wrong patient account (different MRN or chart for same patient)

#### Drug (d)

- Cd1. Failure to order drug
  - a. Failure to order an indicated drug or a corollary order
  - b. Failure to renew or reorder drug (including home, chronic, held medications, antibiotic renewals)
- Cd2. Ordered wrong drug
  - a. Ordered look-alike sound-alike drug (LASA/SALA)
- Cd3. Drug dosage form or formulation not included or missing on order or prescription
- Cd4. Ordered wrong dosage form (IR, ER, SR, XR; tablets, capsules; oral, topical) or formulation
- Cd5. Ordered wrong diluents (IV) or no diluents indicated in the order
- Cd6. Ordered drug to which patient was allergic
- Cd7. Ordered drug that was inappropriate or contraindicated (by lab, disease, age, pregnancy, interactions with other drug, or patient's explicit refusal of drug)
- Cd8. Duplicate order
  - a. Same exact drug
  - b. Same drug different routes
  - c. Duplicate in combination products
- Cd9. Ordered duplicate therapy: different drug same therapeutic class
- Cd10. Ordered a drug that was non-formulary
- Cd11. Ordered a drug that was restricted

### DISPENSING OR ADMINISTRATION ERRORS NOT RELATED TO CPOE (D)

#### Patient (p)

- Dp1. Medications labeled for wrong patient
- Dp2. Medication administered to the wrong patient

#### Drug (d)

- Dd1. Correct drug ordered/wrong drug processed (dispensing or administration issue)

#### Dose (do)

- Ddo1. Correct dose ordered/Incorrect dose processed
- Ddo2. Patient was administered dose lower/higher than ordered

#### Time (t)

- Dt1. Patient received drug product that expires before infusion finished
- Dt2. Patient given drug product that expires before prescribed amount finished
- Dt3. Correct schedule entered but incorrect schedule processed

#### Other (o)

- Do1. Order not verified
- Do2. Nursing process/admin issues
- Do3. Failure to perform or error profiling

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Pt2. Patient received or nearly received drug early

- Cd12. Ordered a drug that was out of stock/drug shortage
- Cd13. Ordered a non-existent, non-available, or no longer marketed drug or packaging

### **Dose (do)**

- Cdo1. Failure to order dose change
- Cdo2. Dose or strength not included or missing on medication order
- Cdo3. Ordered wrong dose or strength
  - a. Incorrect units used
  - b. Ordered wrong concentration or volume
  - c. Ordered unavailable dose
- Cdo4. No infusion rate ordered
- Cdo5. Ordered wrong IV administration rate
- Cdo6. Ordered medication with a problematic dose range
- Cdo7. Problem related to attempt to modify dose
- Cdo8. Medication number or quantity problem
  - a. Quantity not included or missing on order or prescription
  - b. Wrong number or quantity indicated on order

### **Route (r)**

- Cr1. Route missing or not included on medication order
- Cr2. Ordered wrong route on medication order

### **Time (t)**

- Ct1. Time or schedule (frequency) information not included or missing on medication order
- Ct2. Start date not included or missing
- Ct3. Stop date not included or missing
- Ct4. Wrong time, schedule, or frequency entered
  - a. Wrong order date
  - b. Ordered drug product that expired before completion of treatment
  - c. Refill information not entered or erroneously

- entered
- Ct5. Order entered with a problematic time frequency range
- Other (o)**
- Co1.Unable to enter desired order (drug, dose, regimen)
- Co2.Data lost
- Co3.Entered order not routed to/received at intended destination
  - a. Entered order in area not sent to pharmacy (i.e. General Care orders)
  - b. Order entered prior to admission (not routed to inpatient system)
- Co4.Other sig problems
  - a. sig/patient instructions missing or not included on prescription or order
  - b. Incorrect sig/patient instructions
  - c. Conflicting or confusing information on SIG/patient instructions or comments field
- Co5.Problems with template or order set
  - a. Wrong template or order set chosen
- Co6.CPOE problems related to verbal or telephonic order
- Co7.CPOE problems related to IV flush orders
- Co8.Problems related to ordering controlled substance issues
  - a. Signature/DEA # issues
  - b. Print and transmission issues
  - c. Refill/timing issues
  - d. Quantity issues
- Co9. Order entered under incorrect provider
- Co10. Problems with orders for non-drug products

**WHY THE ERROR OCCURRED**

(This “why the Error Occurred” category in the taxonomy was developed based on information from error reports and pharmacists’ clinical experience; however, it was difficult to definitely conclude why the error happened without speaking directly to the person who wrote the report).

- ❖ Order Entry Issues (O)
  - System interface/usability/visual display issues (Ou)
    - Ou1. Adjacency (including pull-down menu) issues
    - Ou2. SALA/LASA issues
    - Ou3. Instructions or medications in comment field were not seen
    - Ou4. Comments field or free text confusing or conflicting with directions
    - Ou5. Use of erroneous system codes or SIG abbreviations
    - Ou6. Difficulty or error in entering initial (start) dose and coordinating with continuing doses
    - Ou7. Lack of adequate system for conveying Hold orders
    - Ou8. Order/reorder modification issues
    - Ou9. Lack of transparency in duration/renewal status
    - Ou10. Order set/template/protocol issues
      - a. Missing template or order set
      - b. Outdated template or order set ordered
    - Ou11. Issues with favorites
    - Ou12. Patient information remained on screen after order was completed
    - Ou13. Visual display confusing or inadequate
    - Ou14. Copy/paste action facilitating error
    - Ou15. Order process was not completed
    - Ou16. Entered order as free text
  - System limitations/inadequacy (Ol)
    - Ol1. Drug formulary issues
    - Ol2. Build issues—route/drug not in CPOE
    - Ol3. Drug dictionary miscode/out-of-date drug information
    - Ol4. Inadequate field length
    - Ol5. Inability/problems in titrating/tapering
    - Ol6. Inability to enter alternate day dosing
    - Ol7. Inability to effectively communicate hold orders
    - Ol8. Error in default dose or schedule
    - Ol9. Default settings facilitating error
    - Ol10. Scheduled drug routing issue
    - Ol11. Pharmacy routing issue
    - Ol12. Corollary orders: timing not properly linked (clarify)

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- O113. Routing or mapping issue
- O114. Drug not available or incorrect in template or order set
- O115. Computer dosing calculation issues
- O116. Weight/ height information not available or inaccurate
- O117. Discontinuation orders not communicated or wrongly interfaced with pharmacy or EMR
- O118. CDS failure/problem/erroneous alert
- O119. Absence of adequate CDS in CPOE system

### ➤ Drug allergy issues (Oa)

- Oa1. Drug ordered as text, unable to check for allergy in text
- Oa2. Failure to alert
- Oa3. Drug allergy field limit
- Oa4. Drug allergy information incomplete/unclear/conflicting
- Oa5. No allergy recorded

### ❖ Computer System Issues (C)

- C1. Computer down or outage
- C2. Hybrid system (electronic & paper)
- C3. eMAR/MAR issues
- C4. Inoperability of Multiple systems (2 or more electronic systems)
- C5. Pharmacy order entry problems or issues
- C6. Inability of CPOE to accommodate individualized TPN orders
- C7. PCA issues
- C8. System malfunction (Bug)

### ❖ Transition Issues (T)

- T1. Failure to perform adequate medication reconciliation
- T2. Patient transferred (within hospital)
- T3. Patient discharged (out of hospital)
- T4. Transferred from outside hospital

### ❖ User Issues (U)

- U1. Communication issues
- U2. Error in Transcription
- U3. Prescription or order needed clarification
- U4. Provider unauthorized to order medication
- U5. 2 different clinicians entered
- U6. Misinterpretation of order(s)
- U7. Lack of computer training or system knowledge

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- U8. Inexperienced end user
- U9. Failure to verify patient identification
- U10. Failure to follow established procedures or protocol
- U11. Lack of protocol knowledge
- U12. Calculation error
- U13. Lack of clinical knowledge
- U14. Alert ignored or overridden
- U15. Typing error
- U16. Nursing administration
- U17. Staff workload increase
- U18. Error in documentation of information needed for prescribing in electronic health record
- U19. Order overlooked

❖ Insurance Issues (I)

❖ Inaccurate or Inadequate Patient Drug Knowledge (K)

## APPENDIX D: BWH MEDMARX CODING GUIDE

1. PCA issues will be classified under “**ordered wrong IV administration rate**”
2. “**Patient received or nearly received dose higher (or lower) than indicated**” vs. “**Delay in medication being given**”
  - a. If prescriber ordered the wrong dose in CPOE and there were no attempts to intervene (by pharmacist, nurse etc.), then what happened to the patient is “**patient received or nearly received dose higher (or lower) than indicated**” (Pdo3 or Pdo4)
  - b. If there were difficulties, discussions, conversation with pharmacy, slowed administration, and confusion, then what happened to the patient is “**delay in medication being given or dispensed**” (Pt1)
3. Out of stock vs. unavailable:
  - a. *Out of stock* means the drug used to be available and is not now, or it is not at pharmacy now but the pharmacy could get it later (delay); includes drug shortages or short supply.  
Temporary issues with supply
  - b. *Unavailable* means the drug does not exist in this form/dose and is currently not marketed in this form. Permanent issues with supply.
4. “**Patient missed dose**” vs. “**patient did not receive medication**” (what happened to the patient)
  - a. “**Patient did not or nearly did not receive medication**” indicates that the patient did not ever receive the medication and there were problems ordering the medication that did not just affect one dose.
  - b. “**Patient missed or nearly missed dose**” indicates that the patient has an active order for the medication, but one or more doses were missed.
5. “**Failure to order drug**” vs. “**unable to enter desired order (drug, dose, regimen)**”
  - a. “**Failure to order drug**” indicates that the user did not even try to order the drug
  - b. “**Unable to enter desired order (drug, dose, regimen)**” means that the user tried to order drug, but could not order it
6. If a nurse increases a dose or administers a drug without an order, it is classified as CPOE related (CPOE failed to prevent)
  - a. What happened in CPOE is “**failure to order dose change**” (Cdo1) or “**failure to order drug**” (Cd1) respectively
  - b. What happened to the patient is “**patient received or nearly received dose higher than indicated**” or “**patient received or nearly received wrong drug**” respectively
  - c. If verbal order resulted in the patient receiving wrong dose or drug, then what happened in CPOE is “**CPOE problems related to verbal or telephonic order**” (Co7), and what happened to the patient would be as listed in b
7. “**Patient received or nearly received drug that was inappropriate or contraindicated**” vs. “**patient received or nearly received wrong drug**”
  - a. If report describes a lab, disease, pregnancy, or patient condition for which a medication is contraindicated, then what happened to the patient is “**patient received or nearly received drug that was inappropriate or contraindicated**” (Pd5) and what happened in CPOE is “**ordered drug that was inappropriate or contraindicated (by lab, disease, age, or pregnancy)**” (Cd7), unless the correct drug was described and there were LASA issues (then what happened to the patient would be “**patient received or nearly received wrong drug**” (Pd2)
  - b. “**Patient received or nearly received drug that was inappropriate or contraindicated**” and is “**ordered drug that was inappropriate or contraindicated (by lab, disease, age, or pregnancy)**”: contraindicated includes DDIs
8. Failure to order home medication is “**Failure to order drug: Failure to renew or reorder drug (including home, chronic, held medications, antibiotic renewals)**” (Cd1b)

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9. CPOE facilitated errors includes errors where:
  - a. CPOE allows user to order something that is not available (permanently unavailable)
  - b. User tries to order a medication and system does not allow it
  - c. Wrong patient errors, unless it is very clear that computer did not facilitate the error
10. BWH CIWA related cases: **Look at BWH CIWA protocol always!** Check the score and the doses the pt should be getting **then** determine what describes what happened to the pt and in CPOE taxonomy. If both wrong dose and wrong frequency of meds happened, pick the 1<sup>st</sup> to classify the error.
11. If the patient gets **2 orders for same med** (regardless if it was on the same day or not) : what happened to the pt is “ pt received or nearly received a duplicate” pd6 (NOT extra dose -pdo2-) and what happened in CPOE is “duplicate order, same exact drug” -cd8a-
12. When there are conflicting SIGs or conflicting info on special instructions or comments field; what happened to the patient is “delay in medication being given or dispensed”- pt1- and what happened in CPOE is “other SIG problems, c. conflicting or confusing information in SIG or comments/special instructions field” -co5c-
13. If computer bug/ glitch causes an order to be discontinued what happened to the patient is “ delay in medication being given or dispensed” - pt1- and what happened in CPOE is “ Data Lost” -co2-
14. For those cases where patients get vaccines again (months or years after) , what happened to the patient is “ Received or nearly received a duplicate” -pd6- and what happened in CPOE is “duplicate order, same exact drug”-cd8a-
15. If there are multiple errors in the same case use the category that describes the 1<sup>st</sup> error that happened. In these cases, what happens to patient is “delay in medication being given or dispensed” - pt1- ( because these multiple errors delayed treatment and pharmacist or nurse tried to contact MD to correct) and what happened in CPOE is chosen based on the first error that they describe in the case.
16. If providers order meds using the wrong template/ order set or outside the template when there is one available in the system (and assigned them under exception orders) and this fact originates errors in medications and doses what happened to the patient is “delayed in medication being given or dispensed” -pt1- because these orders needed to be clarified; and what happened in CPOE is “problems with template or order set chosen, a. wrong template or order set chosen ” -Co6a-
17. For hold orders, when patient gets the med anyway; What happened to patient is Pd02 (patient received or nearly received extra dose (not received a drug that was contraindicated) and CPOE what could be Co4a (entered in area not routed to pharmacy) or other appropriate code.

## APPENDIX E: TEST CASE LIST FOR CPOE FUNCTIONALITY ISSUES

### **Please use a test patient for the following cases**

**Test Case 1:** *When CDS warns about a contraindicated drug (e.g. LASA, geriatric issues), does the alert direct the user to prescribe a more suitable alternative?*

#### **Order instructions:**

1. Use a test patient over age 75.
2. Enter order Diazepam.
3. Does a warning alert fire?
4. Does an alert prompt user to order a different drug instead?
5. Does the alert contain a link?

**Test Case 2: (Inpatient systems only)** *If a medication is unavailable/ in shortage/ non-formulary, does the system alert prescribers and direct them to prescribe the suggested alternative?*

#### **Order instructions:**

1. Enter a drug that you know is non-formulary.
2. Is the drug in the system or do you have to enter it as free text?
3. If the drug is in the system, is there a warning alert associated with it?
4. If there is an alert, is there a link to a formulary medication?

**Test Case 3:** *When free text medications are entered, does the user receive an alert that CDS will not function?*

#### **Order instructions:**

1. Enter *free text* order for Lisinopril 200mg 2 tabs daily.
2. Do you receive a high dose alert or a warning that CDS does not function for free text medications?

**Test Case 4:** *Does CDS function (i.e. is not bypassed) when an inactive medication is reactivated?(mainly outpatient systems)*

#### **Order instructions:**

1. Within your system, is there the option to reactivate an inactive medication?
2. If so, enter an order for warfarin 5mg once daily.
3. Discontinue warfarin order and sign.
4. Enter order for Bactrim single strength, twice daily.
5. Reactivate warfarin order.
6. Do you receive a DDI alert?
7. Enter a new warfarin order.
8. Do receive a DDI alert if you entered a new warfarin order instead of reactivating the old order?

**Test Case 5:** *Does CDS function effectively when products with multiple names (both brand and generic) are ordered?*

#### **Order instructions:**

1. Order Glucophage 500mg, once daily.
2. Order metformin 500mg, once daily.
3. Do you receive a duplicate therapy alert?

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4. What is the alert content (same class alert, duplicate drug, etc)?

**Test Case 6:** *Does the system prohibit the user from ordering half capsules from the structured fields?*

Order instructions:

1. Enter an order for Dilantin capsules 100mg, ½ capsule tid.
2. Was this order with a half capsule able to be placed?

**Test Case 7:** *Do maximum daily dose alerts fire if prescribing Tylenol >4grams + Combo product?*

Order instructions:

1. Enter an order for Acetaminophen 325 mg, two tablets po every 4 hours.
2. Enter an order for Tylenol with Codeine, two tablets po every 6 hours prn.
3. Do you receive a duplicate therapy alert, dose alert, or any other protections?

**Test Case 8:** *Are prescribers prohibited from ordering medications withdrawn from the market?*

Order instructions:

1. Enter an order for albuterol inhaler (plain, not the HFA inhaler).
2. Enter an order for Vicodin 5/500mg 1 tablet every 6 hours prn.
3. Enter an order for Darvon 65 mg 1 tablet every 6 hours.
4. Which, if any of these orders could be placed?
5. What, if any warnings were received when these orders were attempted or placed?

**Test Case 9: (Inpatient systems only)** *Can CPOE accommodate hold Rx orders?*

Order instructions:

1. Enter an order for Coumadin 5mg daily.
2. Enter an order to Hold Coumadin tonight.
3. Describe the steps you have to take in order to place a hold on the order.

**Test Case 10:** *Does blank field checking exist?*

1. In outpatient system: Place an order for amlodipine 10mg daily, but do not include a duration or quantity.
2. Is the order able to be placed with the missing information?
3. In inpatient system: Place an order for amlodipine once daily (no strength).
4. Is the order able to be placed with the missing information?

**Test Case 11:** *Does the system prohibit the user from ordering unavailable or inappropriate units for medication?*

Order instructions:

1. Place an order for Lantus insulin 20 ml SQ QHS.
2. Place an order for Unfractionated Heparin, 500 mg IV/hour (inpatient only).
3. Were/was the above order(s) able to be successfully placed?

**Test Case 12:** *Are prescribers able to completely change the default SIG so that orders are not written with two sets of conflicting instructions?*

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Order instructions:

1. Enter order for Tylenol 325mg tablet every 6 hours x 30 days with a quantity of 200 tablets.
2. Choose 500mg as the dose (take 500mg every 6 hours).
3. Does this order go through with the correct table strength (500mg) and the correct quantity on the label?

OR

1. Enter order for augmentin 250/125.
2. Write 500mg for the dose.
3. Does this order go through with the correct table strength and the correct quantity on the label?

**Test Case 15: (Drug interactions/Interruptive alert required)** *Does an interruptive DDI alert fire for sertraline and phenelzine?*

Order instructions:

1. Enter order for sertraline 100mg daily.
2. Enter order for phenelzine 15mg tid.
3. Do you receive a DDI alert?
4. If yes to question 3, was the alert interruptive?
5. Repeat 1-4 for the following pairs:
  - a. Febuxostat and azathioprine
  - b. Tizanidine and Ciprofloxacin (Tizanidine – CYP 1A2 inhibitors)
  - c. Meperidine and Phenelzine (Narcotic analgesics – MAO inhibitors)
  - d. Clarithromycin and Ergotamine (CYP 3A4 inhibitors – ergot alkaloids and derivatives)

Suggested interruptive DDI alerts	Interruptive Alert	Non-interruptive Alert	No Alert
<i>Sertraline and phenelzine</i>			
<i>Febuxostat and azathioprine</i>			
<i>Tizanidine and Ciprofloxacin</i>			
<i>Meperidine and Phenelzine</i>			
<i>Clarithromycin and Ergotamine</i>			

**Test Case 18:** *Does the system have alerts that assist clinicians with Look-alike/Sound-alike drugs?*

1. For each of the drugs listed below, enter an order and note whether a Look-Alike/Sound-Alike (LASA) alert fires and complete the chart below.
  - a. What does the content of the alert contain? Does the alert give adequate information to help the prescriber choose the correct medication?

LASA Alert	No Alert	Alerts for Only One of Pair (Please Specify)	System Alerts for Both
<i>Glyburide/Glipizide</i>			
<i>Pradaxa/Plavix</i>			
<i>clomiphene/clomipramine</i>			

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<i>ephedrine/epinephrine</i>			
<i>nicardipine/nifedipine</i>			
<i>Toradol/Tramadol</i>			

**Additional Questions:**

1. Does the pharmacy receive electronic notification when a medication is discontinued in the CPOE system?
2. Do alerts fire during the initial order of a medication as well as when the lab for an ordered medication changes (i.e. asynchronous alerts as opposed to synchronous alerts that only fire during the initial order of the medication)?
3. Are CDS alerts and warnings fired during the ordering process (as opposed to after an order is completed)?
4. Do the order entry system and the pharmacy systems use the same knowledge base for alerts?
5. What type of free text fields exist within your CPOE? What are they called (e.g. special instructions, comments, sig)? How do they behave? Are these fields sent to the pharmacy or printed on the label? Is the prescriber aware of which fields stay in the chart, are sent to the pharmacy, and are printed on the label? *Can special instructions be edited?*

## APPENDIX F: PUBLISHED BWH ALERT INFORMATION

Several studies conducted by investigators at Partners HealthCare have examined the rate and appropriateness of alert overrides at the time of prescribing. Research at BWH by Nanji et al. revealed that providers override more than half (52.6%) of all alerts on medication orders, with significant variation in the override rate based on the type of alert; override rates ranged from 24.4% on drug-class interaction alerts to 85.0% on formulary substitution alerts.<sup>35</sup> In addition, they found that almost half (47.0%) of overrides were inappropriate, again with significant variation based on alert type. Only 8.0% of patient allergy alert overrides were inappropriate, while 88.0% of drug-drug interaction (DDI) alert overrides were found to be inappropriate. The results demonstrate the continued need for refinement of clinical decision support at the time a medication order is placed.

Additional work at BWH examined provider override behavior specific to DDIs.<sup>36</sup> The study examined the reasoning, appropriateness, and follow-up of “level 2” (undesirable interaction that could cause serious injury) DDI alert overrides within 36 primary care practices in the Partners HealthCare network. Only 68.2% of DDI alert overrides were appropriate, with “will monitor as recommended” as the most common reason for overriding an alert. Many of the inappropriate overrides put patients at increased risk of serious conditions such as serotonin syndrome, cardiotoxicity, or significant hypotension. Of the appropriate overrides, it was found that the intended actions (e.g., monitored as recommended, adjusted dose as recommended) were completed only 63.3% of the time. In addition, 8 drugs (simvastatin, sildenafil, tramadol, citalopram, amlodipine, tamsulosin, azithromycin, and warfarin) generated nearly 75.0% of all DDI alerts. These results further support the need for refined clinical decision support at the time of ordering, as physicians continue to override alerts for potentially dangerous DDIs.

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<sup>35</sup> Nanji KC, Slight SP, Seger DL, Cho I, Fiskio JM, Redden LM, Volk LA, Bates DW. Overrides of medication-related clinical decision support alerts in outpatients. *JAMIA* 2013; 0:1-5.

<sup>36</sup> Slight SP, Seger DL, Nanji KC, Cho I, Maniam N, Dykes PC, Bates DW. Are We Heeding the Warning Signs? Examining Providers' Overrides of Computerized Drug-Drug Interaction in Primary Care. *PLOS ONE* 2013; 8:1-7.

## APPENDIX G: TOP “SWITCHES” IN BWH LMR

Top “switches” from January 2011 to November 1, 2013:

- “Switch” - one drug discontinued due to “error (erroneous entry) and a new drug ordered on the same day
- Drugs in red indicate drug pairs reviewed
- Drugs highlighted in yellow indicate pairs on the ISMP commonly confused drugs list

D/C'd Drug	New Drug
ERGOCALCIFEROL	CHOLECALCIFEROL
ALBUTEROL INHALER	ALBUTEROL INHALER HFA
OXYCODONE	DOCUSATE SODIUM
BUPROPION HCL	BUPROPION HCL SUSTAINED RELEASE (12 HR TAB)
OXYCODONE	IBUPROFEN
FLUTICASONE NASAL SPRAY	FLUTICASONE PROPIONATE NASAL SPRAY
METOPROLOL TARTRATE	METOPROLOL SUCCINATE EXTENDED RELEASE
CALCITRIOL	CHOLECALCIFEROL
CALCIUM CARBONATE/ VIT D 1500 MG/200 IU(600 MG ELEM CA)	CALCIUM 600MG + VITAMIN D(400IU)
AMPHETAMINE/DEXTROAMPHETAMINE	AMPHETAMINE/DEXTROAMPHETAMINE SR
DOCUSATE SODIUM	OXYCODONE
PREDNISOLONE 1% ACETATE OPHTHALMIC SUSPENSION	OFLOXACIN 0.3% OPHTHALMIC SOLUTION
KETOROLAC TROMETHAMINE 0.4 % OPHTHALMIC SOLN	OFLOXACIN 0.3% OPHTHALMIC SOLUTION
OFLOXACIN 0.3% OPHTHALMIC SOLUTION	PREDNISOLONE 1% ACETATE OPHTHALMIC SUSPENSION
METOPROLOL SUCCINATE EXTENDED RELEASE	METOPROLOL TARTRATE
OXYCODONE 5 MG/ACETAMINOPHEN 325 MG	OXYCODONE
ALBUTEROL	ALBUTEROL INHALER HFA
FLUTICASONE FUROATE NASAL SPRAY	FLUTICASONE PROPIONATE NASAL SPRAY
NULYTELY	BISACODYL-PEG ELECTROLYTE SOLUTION
OXYCODONE	HYDROMORPHONE HCL
KETOROLAC TROMETHAMINE 0.4 % OPHTHALMIC SOLN	PREDNISOLONE 1% ACETATE OPHTHALMIC SUSPENSION
VENLAFAXINE HCL	VENLAFAXINE EXTENDED RELEASE
TRIAMTERENE 37.5 MG/HYDROCHLOROTHIAZIDE 25 MG CAP	HYDROCHLOROTHIAZIDE
OFLOXACIN 0.3% OPHTHALMIC SOLUTION	KETOROLAC TROMETHAMINE 0.4 % OPHTHALMIC SOLN
INSULIN GLARGINE	INSULIN GLARGINE SOLOSTAR PEN
BUPROPION HCL	BUPROPION HCL EXTENDED RELEASE (24 HR TAB)
CHOLECALCIFEROL	ERGOCALCIFEROL
IBUPROFEN	OXYCODONE
OXYCODONE CONTROLLED RELEASE	OXYCODONE
PREDNISOLONE 1% ACETATE OPHTHALMIC SUSPENSION	KETOROLAC TROMETHAMINE 0.4 % OPHTHALMIC SOLN
METFORMIN	METFORMIN EXTENDED RELEASE
TIMOLOL 0.5% OPHTHALMIC SOLUTION (PF)	TIMOLOL MALEATE 0.5%
OXYCODONE	HYDROCODONE 5 MG + APAP 500MG