AHRQ Grant Final Progress Report for:

Blackbox: A Multidisciplinary Team-Based Framework for HIT Error Pattern Detection

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Structured Abstract

Purpose: To outline a novel approach to retrospectively identify and analyze EHR-facilitated errors based on the concept of a Health IT BlackBox (flight data recorder).

Scope: Foundational research has explored health information technology (IT) errors which have started surfacing with their rapid adoption. There has been a focus on understanding what kinds of errors have started occurring, but few tools exist to determine why these errors occur and how to make informed changes to improve the EHR.

Methods: A retrospective methodology was utilized to identify EHR errors with the goal of clinical systems optimization. This methodology included data driven error pattern detection, point of error video capture and retrieval, multidisciplinary error review and recommendations for system improvements.

Results: Five error types were explored: 1) Wrong Route queries identified 38 cases with 16 reviewed and classified as likely or highly likely errors with a rate of 7.4 error per 1,000 suppository orders 2) Wrong Weight cases revealed 54 cases of interest with 15 confirmed cases of error with 8 heuristic violations on detailed EHR interface review 3) Wrong Sided errors revealed 472 cases of interest with 69 cases reviewed and 46 classified as likely or highly likely errors. 4) Free-Text orders were sampled from approximately 3.2 million orders and 42% of 5,574 orders contained medication information despite direction otherwise 5) Wrong Route orders describing 196,769 potassium orders and demonstrated 697 definitive errors. The Health IT BlackBox methodology was successful in identifying and reviewing multiple EHR based errors and providing design guidance.

Key Words: Patient Safety, Health Information Technology, Error Detection, Post-Surveillance Monitoring

Purpose

Although health information technology systems include rudimentary safety checks, many errors remain undetected and become near misses or serious safety events. While these clinical decision support systems are helpful in identifying errors at the point of care, they provide no insight as to their cause. The purpose of this project was to outline a novel approach to retrospectively identify and analyze EHR-facilitated errors based on the concept of a flight recorder or black box.

Scope

The adoption of electronic health records (EHR) have soared since the passage of the 2009 Health Information Technology for Economic and Clinical Health Act authorized payments through Medicare and Medicaid.[1] In fact, as of 2016, over 95% of these eligible hospitals have meaningful use certified EHRs in place.[2] While this widespread adoption of EHRs and computerized physician order entry (CPOE) has likely made the healthcare industry safer for patient care, these systems have not been optimized for safety. It is becoming increasingly clear that there is a need to focus on ensuring that these systems are safe to use.[3]

Foundational research has explored the newly emerging landscape of health information technology (HIT) errors which have only started surfacing in the last decade. There has been a focus on understanding what kinds of errors have started occurring as a result of electronic interfaces for caring for patients. Previous research has found that CPOE systems may have reduced medication prescribing errors by up to 81%.[4] However, this research also outlined 22 distinct error types that can occur as a result of physician electronic ordering including medication duplication, dangerous interactions, and automatic unexpected discontinuation of certain medications types. While understanding the types of errors which occur is a necessary and significant starting point, the next step is to understand why these errors happen so that recommendations can be made as to how they can be avoided in the future.

Other high-risk industries, like aviation, defense, and nuclear energy have focused on the “context of use,” or the conditions under which the errors occur, and have often put technological systems in place to capture the context around errors. For example, aircraft are equipped with flight data recorders, often referred to as black boxes, that allow for retrospective analysis of events. The combination of the technology to capture the events and use of human factors engineering to study the context around the events has been critical to providing better designs and preventing predictable errors. In healthcare, we currently lack the methods and data necessary to answer these questions in situ with EHRs. The objective of this paper is to introduce our novel framework in order to analyze recorded video of clinical EHR use in order to understand how EHR-related safety hazards happen and what design elements contributed to the error.

Methods

The framework discussed subsequently describes a recurrent methodology to identify EHR supported errors with the goal of clinical systems optimization thereby reducing the risk of an avoidable adverse patient safety event. The preliminary steps in the process is the a priori identification of error types and patterns. These error types were chosen by subject matter experts in the field of medicine, usability, human factors, and safety science and frequently the subject of patient safety reports entered by front line clinicians during everyday patient care. The initial error patterns to detect were adapted from work of Adelman et al[5] where an order is placed on a patient canceled, then quickly re-ordered on another patient; indicative of a wrong patient identification error. The described methodology initially applies a similar temporal pattern of order, cancel, re-order while localizing on a single patient. However, instead of being limited to just wrong patient errors, this work was adapted to focus on a variety of areas of poor cognitive support of the users in the EHR. The process diagram for the framework is shown below in Figure 1.

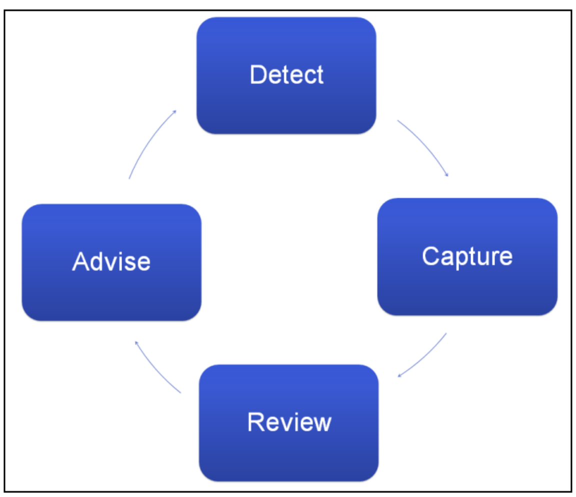

Figure 1: Process diagram of the recurrent "Health IT BlackBox" framework

1. DATA DRIVEN ERROR PATTERN DETECTION

The initial investigation of error patterns focused on instances where providers chose the incorrect route of administration, the dosing frequency of long acting opioids, and the laterality of diagnostic imaging. The challenge of detecting and profiling specific provider order entry errors in a regional healthcare delivery network as large as MedStar Health, is analogous to finding the proverbial needle in a haystack. The initial set of database queries were limited in scope to the emergency department, inpatient, and observation patients in eight tertiary care facilities which share a centralized and searchable clinical data repository based on a single electronic health record. The temporal chain of events consisted of single patient centered and includes a provider placing an order, subsequent cancelation irrespective of the time interval, and ultimately re-ordering an identical therapeutic or diagnostic test type yet with a different route, frequency, or laterality. This was an important distinction from previous work describe by Adelman et al. that a priori chose a 10 minute elapsed time without a sensitivity analysis to determine if error case occurred in the time period beyond 10 minutes.

In order to detect these patterns, a diverse set of tools are utilized. MedStar Health's primary clinical data repository is housed in the highly relational Cerner Millennium EHR database. The complex architecture of parent child relationships is optimized for writing data from users and inbound external data, but is computationally expensive for processing and extracting large volumes of data. To meet this challenge, Cerner's Discern Explorer suite is utilized to develop functional specifications and map relevant data elements. Once the preliminary work is completed, the query itself is run against the production database implemented in Cerner Command Language (CCL). The key data elements extracted are 1) the name of the provider who ordered, canceled, and re-ordered the orderable 2) the time of each action 3) the full order details for both the initial and subsequent order.

2. POINT OF ERROR VIDEO CAPTURE AND RETRIEVAL

The innovative methodology utilized in the Health IT BlackBox is the addition of screen capture during the clinical interaction with the EHR. In 2017 MedStar Health implemented recording of every user session in the EHR. This methodology uses commercial software from TS Factory (https://www.tsfactory.com/) to capture user sessions at the time they are using the software as they log in through Citrix software to the Millennium EHR in a client-server model. Initially implemented to assist in clinical informatic help desk calls, the software enables IT staff to review the specific interactions that correspond to user concerns. These recorded user interactions, videos of the computer screen including mouse movement and keystrokes but no user facing video, are stored for approximately seven days and then deleted to make room for additional videos. Our team utilized this capability to not wait until a user filed a ticket or concern about the EHR, but to proactively detect errors and then observe how the technology was utilized in the context of everyday use.

Leveraging the key data points compiled in step 1 above, a database search is performed of the user activity logs to find a unique session and duration which is then cross referenced to match this unique digital fingerprint to the corresponding screen recording. The screen recordings are then saved on a secure server as cases of interest to be analyzed with other similar events, typically in sets of 15. This follows the traditional usability methods that use between 10 to 15 users to detect the majority of use errors of a given user interface (discussed below).

Due to the storage limitation of the MedStar Health system the team was required to run the queries for each error type (e.g. wrong route, wrong side, etc.) on a weekly basis to maximize the chances of capturing use errors in the EHR. As a proof of concept, the team was able to partially automate this process and create an internal website that allowed less-technical research staff members to run the queries and determine if any new cases of interest had occurred since the previous week. In addition, the location of the user sessions and key demographics were displayed to allow rapid access. This cut down the time to locate a case of interest from approximately 60 minutes to less than 15 minutes. In addition, the team helped trouble shoot technical challenges with the screen capture system that initially resulted in user sessions not being properly recorded.

3. MULTIDISCIPLINARY TEAM VIDEO REVIEW AND CODEBOOK

Once a set of approximately fifteen cases of interest are collected for a specific error type (e.g. wrong route, wrong side, etc.) the team performed an initial evaluation of the case series to determine potential commonalities and a standardized set of variables to extract from each case in the series. This process was performed with clinical subject matter experts, human factors specialists and clinical informaticians in a multidisciplinary approach. Once the clinical and informatics based variables were selected each case was coded by a team member and variables were extracted, including elements such as time of error, time of correction, which step in the order process where the error occurred and where and when it was recognized and if any alerts or warnings helped the user recognize the error. This allowed the team to standardize their approach in coding if an error occurred and what the evidence was behind each case the accuracy of the queries in detecting errors. In addition, it helped reduce potential bias by guessing at time intervals or specific causes of the errors. In addition to the manual abstraction of time stamps and data from the video, each video and patient chart was reviewed by a clinician (physician, nurse or pharmacist) to determine if there was additional evidence that would support the likelihood that an error occurred, if a pause in workflow occurred and other elements. For example, if there was concern that a rectal suppository was ordered instead of an oral tablet the clinician could perform a chart review to see if the patient was receiving other oral medications or if they had an order for "Nothing Per Oral (NPO)" that may support decision making. While some of these clinically important variables were not always present on the screen, they could not only determine accuracy of the error detection as mentioned previously, but could also be used to help determine potential solutions, including new interface elements, changes in workflow or triggers for alerts. All elements were included in the codebook (Appendix A) and cases were assigned a likelihood of error based on the findings of the review process. Cases were assigned as an unlikely error, a possible error, and a highly likely error. The specific elements that determined assigning likelihood were different per each case and agreed upon by the group with an iterative approach if a new type of error or uncertainty was discovered in each case series.

4. SATURATION METRICS

As the methodology continues to identify, capture, code, and analyze an increasingly larger set of cases, a point of diminishing returns is reached known as saturation. This is defined as the point at which analyzing more data will not add new information. In this study, it is the point at which, searching for, capturing, and coding videos of EHR interactions no longer yields additional insights into EHR supported error patterns. There is, unfortunately, no consensus definition of how to quantitatively calculate the point of saturation. In its comprehensive review of the saturation methodology, [6] four essential metrics were identified to establish that data analysis has reached saturation. Of the methods detailed in this paper we chose the direct model of Data saturation with a principle focus on data collection. To calculate the saturation metric our framework set a goal of collecting twelve cases to develop the codebook then coding 3 more videos to determine whether any new information can be gleaned. The saturation analysis will be discussed in the results section.

5. IDENTIFICATION OF EHR ERROR CONTRIBUTIONS AND POTENTIAL SOLUTIONS

Ultimately this research was seeking to develop a methodology that could not only detect errors and review what the clinician was seeing at the time of the event, but more importantly evaluate the interface and identify potential solutions to preventing the errors from happening repeatedly. Our prior work noted that some public EHR vendor usability testing did not test their interfaces with representative clinical cases or with clinical end-users.[7] We hypothesize that this lack of representative formative testing could allow for designs that do not support the cognitive needs of the clinical user in the live clinical environment that is ripe with interruptions and complex tasks across multiple users. One key finding detailed below is the role not just of design changes made during implementation, but the "EHR bloat" that occurs overtime as new features and minor adjustments to the EHR impact the usability of the system. These impacts are likely to go unnoticed by informatics teams and go unreported by front-line users that don't appreciate the impact of EHR usability on their daily workflow while caring for patients. However, it is these EHR usability challenges that have direct impact on the orders that clinicians place, information they visualize and data that that is entered into the EHR. The queries themselves can then be monitored in an ongoing basis to see if the suggested changes to the EHR have the impacted effect on workflow and can be used to monitor for potential new hazards as the EHR is upgraded or modifications are made with unintended consequences.

Results

The research team developed queries that reviewed electronic orders across nine institutions. Cases of interest across five error types (including wrong route, wrong weight and wrong dose among others) were identified for further review. Of those cases of interest the team performed manual review of cases and assigned likelihood coding to each event until saturation of cause occurred. Each of the error types (Wrong Route, Wrong Weight, etc.) will be explored in greater detail below. Because of the iterative approach to developing the Health IT BlackBox methodology some of the error types were more further developed than those developed at the later stages of the project and will be outlined below.

Wrong Route

The initial query that the team developed centered around the delivery of medications via the wrong route. The team chose a known error in the EHR where it was observed that multiple clinicians across multiple sites would order acetaminophen (Tylenol) via the rectal route (PR=Per Rectum) instead of Per Oral(PO). Although these routes are clinically equivalent for this medication, there are some medications that can cause serious harm or death if given via the wrong route, such as intrathecal (spinal injection) instead of intravenous. In order to identify potential errors, the team looked for evidence of a clinician entering an order for PR acetaminophen and then having it canceled due to patient refusal, provider recognition of error or the nurse questioning the order. Using the sequence of events of a PR order placed on a patient, canceled and then a PO order written the searched for potential wrong route errors. Because the screen recording were only held for 7 days the team ran the query once a week for approximately three months to capture enough cases for analysis. At the end of the period 38 cases of interest were identified by the query. On further review 22 cases were excluded, 7 removed as duplicates due to overlapping query periods and the remaining were corrupted files in the storage system that prevented viewing the encounters. The corrupted files were believed to be secondary to users having multiple EHR sessions open (either across multiple computers or on the same workstation). After some investigation and changes within the EHR, the corrupted video files occurred infrequently for the remainder of the project. The remaining 16 cases were then reviewed from a clinical perspective to categorize the likelihood that they represented an error, with 12 as highly likely and 4 possible errors using the criteria in the CodeBook (Appendix A). This gave an overall error rate of 42 % (16 highly or probable errors / 38 cases of interest).

In order to put this error rate in the context of all orders for acetaminophen the team sought to understand the likely error rate across the system and the amount of potential improvement that could be expected if all acetaminophen wrong route errors were designed out of the system. The team determined that during the 12-month period (that included the 3 months of errors above), 197,621 unique orders were placed (4,574 PR orders and 193,047 PO orders). Using the same wrong route query that was identified above we retrospectively identified 82 cases of interest during this period. Because of the retrospective nature of the query we were unable to obtain screen capture of all of the remaining cases, so it was estimated that 42% of the case of interest would be confirmed highly or possible errors for approximately 34 errors. Stated differently, a conservative estimate is that 34 of the 4,574 rectal suppository orders were likely in error, or approximately 7.4 wrong route errors per 1,000 tylenol suppository orders.

The team next evaluated the potential interface design that may have contributed to the user either performing the hazard or how the system may have prevented the user from catching the error at the time it occurred. On review of the cases 14 of the 16 errors happened at the point the clinician chose a medication order sentence. For context, in the EHR under study requires the ordering provider to select the medication by name, in this case “acetaminophen” and then the user is presented with a pre-populated set of “order sentences” (figure 2). On review of the list it is not clear how the information is sorted, if there is a significant clinical distinction between some of the options as well as the utility of giving the option for a recurrent dose of acetaminophen in a setting like the emergency department where it is likely the patient will not be in the ED long enough to receive a second dose. In this analysis 14 of 16 of the highly likely and possible errors occurred during the selection process from lists similar to the one in this figure. On review of the videos, 100% of 14 user with selection errors users always chose an element that was above the item they intended, with a range of 1 to 4 lines above the intended target (mean 2.6).

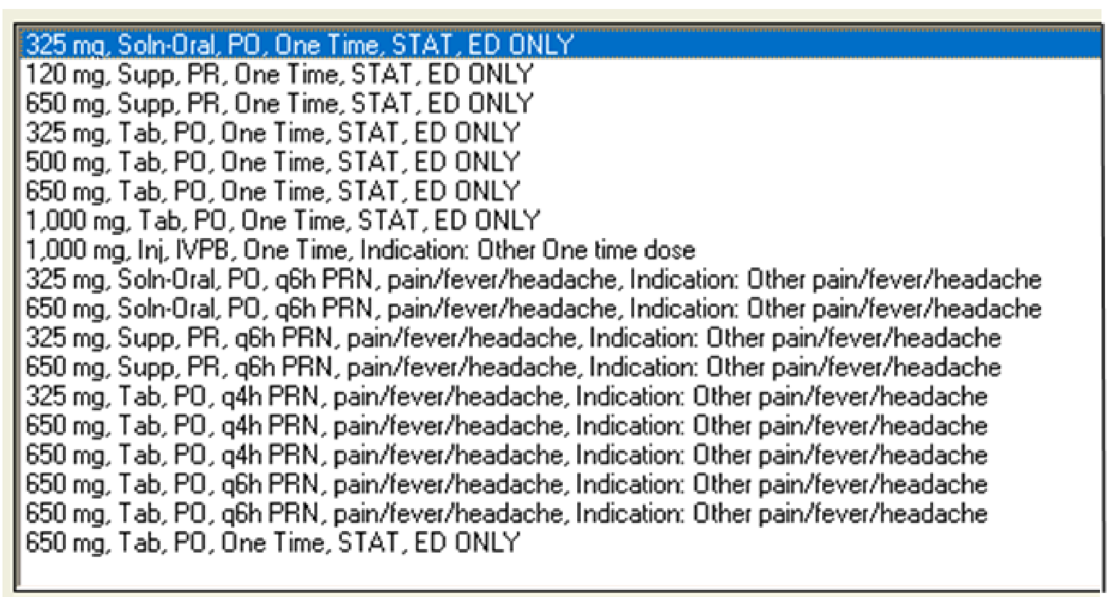

Figure 2: A view of acetaminophen order sentences for an emergency department provider.

On further analysis of the EHR it was noted that different providers in different clinical settings would be presented with slightly different lists of acetaminophen orders. Initially the EHR was implemented to ensure that only those order sentences that were appropriate for the given clinical scenario were visible to the front end user. However, over time the governance structure was not sufficient to prevent bloat and orders were added to different order sets or different clinical locations as they were added to the EHR. This resulted had the unintended consequence of duplicate and unnecessary orders being visible by the wrong user and consistently resulting in a wrong route error. On further investigation, the system contained over 500 different order sentences that clinically only could likely be reduced to less than 10 order sentences.

In addition to publications listed below, the work was presented internally within the health system and lead to an initiative and partnership with Cerner to review the one hundred most prescribed medications in the system and remove duplicate or clinically irrelevant items for users.

Final Usability Recommendations:

1. Clearly differentiate between options in a list
2. Place the most used items at the top of the list
3. Remove items that are infrequently used
4. Provide options for users to customize orders

Wrong Weight

The second error type that was investigated included errors in entering a patient's weight into the EHR. Specifically, the team was interested events where the user entered pounds into a kilogram field. Like the wrong route error, the team looked for an event where two weights were entered into the EHR during the same visit and the second weight was at least twice the second weight.

Through this analysis 54 cases of interest were identified with 27 duplicate and 6 corrupt files. The remaining 21 cases were captured in the Health IT Blackbox library and the first 15 cases were reviewed determined to be consistent with highly likely errors. Due to the specificity of the query no cases were determined to be possible or unlikely and the remaining 6 cases were not reviewed because saturation was reached. The team was unable to determine error rates due to the large number of weights recorded within the EHR and poor accessibility of these measurements of the system. Many EHRs, including the one used in this study, are highly relational and optimized to receive data entered by many users on few patients. They are not designed for a single user to obtain data on many patients across many tables within the EHR database. As a result the team was only able to study the identified cases. This problem has since been overcome, but at the time was a rate limiting step. Lastly, the screen capture did not allow the research team to confirm the reading on the manual scales in the individual offices, only infer that the scale must have been measured in pounds as the most likely cause of the error.

On deeper analysis of the data the team noted that the 15 errors occurred 11 different sites with 3 clinics having more than one event and only one user having more than one event. As a result the team did both an onsite and remote review of the clinics and found several commonalities, including scales that measured in pounds or had the ability to be switched back and forth. On discussion with the medical technicians they stated that sometimes they would switch the mode of the scale to show children's parents what the weight was in pounds due to parent unfamiliarity with using kilogram.

While scales and family expectations around units of measurement may have been the root cause of the problem of wrong weights being entered it was clear that the EHR was not supporting the user in catching the error at the time of data entry. As a result, the team performed a heuristic analysis of the 15 videos containing wrong weight errors using the Neilsen-Shneiderman Heuristics. A report was completed that identified specific design elements that facilitate errors, including seven violations spread across eight heuristics. These heuristic violations are grouped into the following:

1. Inadequate ranges for triggering alerts
2. Lack of informative feedback, flexibility, and good error messaging surrounding alerts (alerts can be easily and inadvertently deleted, alerts do not flow to physician when changes in weight input are made)
3. Utilization of metric system with patient desire for information in imperial system
4. Inaccessible weight conversion calculator
5. Lack of reference to historical weight data to serve as an accessible reference

These heuristic violations were communicated internally within the health system and discovery was made with inconsistencies in the intake forms for adult and pediatric patients that may have led to height and weight entry confusion, a related health IT error type. Changes to electronic forms were put in place as well as standardizing scales and workflow across all ambulatory locations. These findings will be more broadly disseminated in coming publications.

Wrong Side

Wrong sided surgeries are a never event in modern healthcare yet they continue to happen on a consistent basis. The research team elected to look for events that were lower severity in terms of patient harm but nonetheless could help better understand why issues of wrong sided procedures happen. The team investigated evidence of diagnostic imaging studies that occurred on one side of the body when the clinician intended to obtain imaging of the other side of the body. The queries included any imaging modality that designated one side of the body or the other. For example, a right wrist x-ray or left lower extremity CT scan. In addition to searching for a specific sequence of events where an imaging study was canceled and then reordered on the same part of the body but the other side the team had to develop a key word search strategy that identified which side of the body each imaging study was located on to identify an event where alternating sides occurred. It was important for the team to filter out the frequent instance where images of both sides of the body may be indicated, such as in a traumatic car accident.

The query produced 472 cases of interest with 85 event videos reviewed by the clinical expert team. Because of the variability of cause the team went through multiple round of review until saturation was achieved. Ultimately 69 cases were scored by the research team with 31 highly likely, 15 possible events and 23 unlikely cases. Chart reviews were particularly necessary to confirm cases where triage, nursing and provider notes could be reviewed to determine where the patient's side of injury was located and if it was incongruent with the initial order that was placed in the system. While not incorporated into this query, natural language processes could be employed in the future to remove the manual chart review that was required in this study to determine the likely ground truth for which side of the body required imaging.

On analysis of the videos the team determined several different reasons for why these errors seemed to occur with frequency. The most common source of error (n=45) was the selection of the wrong side from a list of options, similar to the previously described acetaminophen wrong route error. The remaining errors occurred during the modification of either order sets or the use of favorites where a provider stored an order or an order set and did not modify the laterality of the imaging studies. This included the use of post operative orthopedic order sets where the a post-operative x-ray was pre-selected as right or left and the surgery was on the opposite side. The clinician may document in their note and diagnosis the correct side, but either forget or do not recognize the need to change the side specific issues on the order set.

Potential solutions for these errors include

1. CDS alerts for providers that note incongruent sides documented in the providers notes, imaging studies, procedures and diagnosis codes as well as documentation from other providers, especially nurses.
2. Carefully designed ordering screen that take into account laterality when displaying lists of orderables
3. Consider laterality of x-rays when designing order sets and take into account potential hazards if users save order sets with favorites

These will be addressed further and disseminated in the upcoming manuscripts listed below.

<u>Hypothesis Generation Cases</u>

Free Text Medication Orders

As a pilot study the team explored the use of free-text orders in the EHR as a possible marker for poor usability of the EHR. Specifically, the team was interested in investigating a specific orderable called a "Communication for Non-Medication Order". These electronic orders allow a physician to place a date and time stamped verbal order in the EHR. This particular order is named in such a way as to discourage the use of the order for medications as a work-around due to it bypassing safety mechanisms and presenting potentially important information in an EHR location that other staff members may miss. Anecdotally the team had examples of this order being used to transmit information that had other more formal methods, such as medication orders as well as diet order and diagnostic testing orders.

A query was developed to search for instances when medical information is written in a non medication order (NMO). The EHR database was searched and all NMOs were extracted (approx. 3.2 million) from 6 hospital locations between 2013-2017. A content analysis was completed and 16 distinct categories of instances were identified in which non-medication orders are used. The team sampled 26,542 orders from the year 2017. The sample contained 5,574 unique texts. Coding of these samples achieved an IRR of 0.82 between two coders that was established on 10% of these data. Over 42% of orders were found to contain medication related information. The context represented in the free-text was also coded, and four distinct contexts were identified, including: If the order contains a certain condition associated with it, if the order has sequential or temporal information, if the order communicates about temporal array of patient states, if the order communicates information that is related to situational awareness. The outcomes associated with these coded orders are currently being analyzed and will be submitted for publication shortly and supported the PhD thesis of Swaminathan Kandaswamy, PHD (Awarded September 2019) at University of Massachusetts-Amherst.

Wrong Route: Potassium

A query was developed to analyze wrongly entered medication routes and examines orders that were placed, canceled, and a new order was placed for the same medication (Wrong Route) where the team did not have a definitive event sequence for analysis like was demonstrated in the PR-PO acetaminophen order. Potassium was identified as a potential source of these order changes due to the frequent changes between intravenous and per oral dosing as well as being a high-risk medication if the route, amount or rate of medication is written incorrectly. Analysis of the erroneous workflows of placing an order for potassium, canceling it, then reordering potassium demonstrated this sequence of events only happens the minority of the time. Occurrences of this sequence of events were reviewed for a single year, totaling 196,769 orders. Of these, approximately 0.4% were classified as likely or definite high-risk orders, including 697 definitive errors that are not safe to give to a position under any circumstances.

Limitations

Overall the study was limited by developing the methods for not only finding the needle in a haystack of health IT related errors, but then linking them to screen capture during the event and identifying specific usability elements that contributed to the error. Some events could only be categorized as possible or unlikely errors without additional chart review data. Future queries could take increasing complex approaches and consider employing machine learning techniques to not only identify but potentially predict errors as they are happening. Finally, translating findings into changes in the EHR takes significant effort and often requires alignment with diverse stakeholders and navigation of the greater informatics community. However, the ability to demonstrate errors through video review can provide a powerful story for how quickly and easily EHR errors can occur.

Future Steps

There are several next steps that the research team is pursuing. First the team will continue to promote the use of screen capture and the Health IT BlackBox methodology. The technique has been incorporated in multiple venues in the health system, including with the risk management teams to identify EHR usability concerns when at the time a patient safety event is recognized. The method has already been used to help identify potential issues that may have otherwise gone unrecognized. Second there are several publications listed below that are in the process of being completed and submission for peer review, including two that will be submitted to the Journal of the American Medical Society. Lastly, the team will be using the Health IT BlackBox in a current R01 grant to study the electronic Medication Administration Record. A revised R01 proposal will be submitted this November to build a functional Health IT BlackBox that addresses many of the manual processes and lessons learned from this project. The team will plan to use the methodology to study the cognitive needs of clinicians when identifying patients at risk for harm from opioids and assist with treating acute pain in the ED.

Conclusion

This project has demonstrated the feasibility and value of creating a methodology and process for a Health IT BlackBox. The value of seeing through the eyes of the clinician at the exact moment that an error occurs is a powerful tool for change that is amplified when the same error is demonstrated to happen across institutions, providers and settings within a common EHR. Healthcare is quickly moving away from the "Name, Blame and Shame" attitude of pointing fingers at front line staff and now it needs the tools to not only identify when systems based issues are going on, but also to understand why they are happening and how those issues can be designed out of the system. Health IT systems like the EHR have frequently been pointed as sources of error and frustration, but with the active study of errors across systems we can put active surveillance in place like the Health IT BlackBox and collaborate to truly design systems that make it easier and safer to care for our patients.

List of Publications and Products

- Hoffman, D., Blumenthal, J., Mosby, D., Distaso, C., Ratwani, R., Hettinger, A.Z.*A Novel Method in Building an Active Health IT Surveillance BlackBox: Medical Intelligence*. AMIA 2018 Clinical Informatics Conference. May 9 2018, Scottsdale, AZ (Poster Presentation).
- Hoffman, D. J., Blumenthal, J., Mosby, D., Distaso, C., Ratwani, R., Hettinger, A.Z. *A Novel Method in Building an Active Health IT Surveillance BlackBox: Medical Intelligence.* MedStar Health Research Institute Research Symposium. April 30 2018, Bethesda, MD (Poster Presentation).
- Krukas, A., Hoffman, D., Kandaswami, S., Blumenthal, J., Weldon, D., Stein, L., Berner, E., Hettinger, A.Z. *Trigger Identification of High Risk Medication Orders: Potassium as an Example Study.* Human Factors and Ergonomics Society Healthcare Symposium. March 26, Chicago, IL (Poster Presentation).
- Combining Human Factors and Data Science Methods to Evaluate the Use of Free Text Communication Orders in Electronic Health Records Swaminathan Kandaswamy (PhD Thesis – Submitted September 2019)
- Kandaswamy S., Hettinger A.Z., Hoffmann D., Ratwani R.M., Marquard J *Communication through the Electronic Health Record: Frequency and Implications of Free Text Work Arounds* (Under Development for JAMA – Expected October 2019 Submission)
- Hettinger A.Z., Blumenthal J., Hoffman, D. Ratwani R.M. *Proactive EHR Usability and Safety Surveillance* (Under Development for JAMA – Expected October 2019 Submission)
- Krukas, A *Trigger Identification of High Risk Medication Orders* (Masters of Clinical Informatics Capstone Project – University of Alabama – Birmingham)

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Appendix A - Health IT Error Codebook

Wrong Route

Error	Definitions
Likely	1. No other PR medications 2. Have other PO medications 3. No NPO status 4. Been less than four hours between PR and PO order
Possible	1. If it does not fall within above, then perform chart review 2. In the chart review, look for notes and evidence of transitioning the patient from NPO to PO status
Unlikely	1. Patient is on another PR medication presently 2. No PO medications. 3. There is a NPO status. 4. What is the time between PR order and PO order 3. A generous cut-off is four hours, if > four hours, it is an unlikely error
Point of Error	1. Selection: selected wrong sentence or order in drop down/list 2. Modification: altering/renewing prior order, no modification

Wrong Side

Error	Definitions
Likely	1. Provider note and Triage note both indicate right but provider ordered left (or vice versa) 2. <4hr between each order 3. Radiology ultimately only completed imaging on the appropriate side of the body 4. Solely ordered one side
Possible	1. If it does not fall within the two above mentioned camps 2. Both sides ordered (Right & Left) 3. Conflicting provider documentation. e.g. triage note says R, provider note says L
Unlikely	1. Provider note and Triage note both indicate same side or opposite side. 2. >4 hr between each order indicating patient's clinical status may have changed. 3. Chart review of provider note justifies order placement
Point of Error	1. Modification: incorrect modification of an existing order a. Pre-set order b. Provider orders right but writes left 2. Selection: selected wrong order from dropdown list

Wrong Dose: Oxycodone

Error	Definitions
Highly Likely	Less than or equal to Q8 hour Oxycotin or long acting oxycodone ER
Possible	Previously taking less than q8 hour oxycotin/oxycodone ER or palliative/hospice care
Unlikely	N/A
Point of Error	During the ordering process or med reconciliation

Wrong Weight

Error	Definitions
Highly Likely	1. Patient's weight does not register on CDC/ WHO growth scales 2. Not off scale but not consistent with prior documented weights 3. User corrected patient weight during same encounter
Possible	N/A
Unlikely	N/A
Point of Error	When form saved

Wrong Patient

Error	Definitions
Highly Likely	1. "Order voided within 10 mins of new order being written for same pt by same provider, with reason for void being" – Retract and Reorder Tool Definition 2. Current query- +/- 60 min 3. Next query +/- 4 hours
Possible	N/A
Unlikely	N/A
Point of Error	1. Order written for wrong patient and then voided with reason "wrong patient/wrong encounter". 2. 2 ways of identifying: cancel and reorder; specifying reason for void. 3. Selection Error (chart selection/similar name/similar location/similar diagnosis) 4. Interruption Error? (possibly interrupted during chart action and then places an order)

Wrong Dose: Potassium

Error	Definitions
Definitive	1. Any route outside of PO, feeding tube, or IVPB/IV/IV Inj. (for example, IV Push or Subcutaneous) 2. Individual Enteral Route + Dose > 80 mEq (for example, 400 mEq) 3. IVPB/IV/IV Inj + Frequency time interval shorter than Q1H +Unconfirmed rate of administration + Dose/time interval in units of hours > 20 mEq/hr 4. Rate of Administration > 20 mEq/hr 5. IVPB/IV/Iv Inj Route + Dose > 10 mEq or Rate of Administration > 10 mEq/hr + Confirmed Peripheral Line
Likely	1. IVPB/IV/Iv Inj Route 2. Dose > 20 mEq 3. Unconfirmed Rate of Administration
Possible	1. Dose > 10 mEq + IVPB/IV/IV Inj + No confirmation of central line +No confirmation of RoA <= 10 mEq/hr 2. Individual Dose > 40 mEq + Enteral Route
Unlikely	1. Normal course of therapy 2. No criteria above apply
Point of Error	Modified orders – changes in dose/route/frequency