Understanding Clinical Information Needs and health Care Decision Making Processes in the Context of Health Information Technology

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2. Structured Abstract

Purpose: The goal of this project was to understand the basic science of missed test results.

Scope: Delayed diagnoses resulting from test result communication failures ("missed" test results) are a significant safety concern in outpatient settings and often lead to patient harm and malpractice claims. To define the context of clinical work related to EHR-based test result follow-up in natural settings, we used a conceptual model derived from human factors engineering principles which posits a set of eight socio-technical dimensions that must be considered in the real-world use of IT. This foundational work will be instrumental to address the problems of follow-up of abnormal test results in EHR-enabled outpatient.

Methods: We conducted critical decision method-based cognitive task-analysis of providers who ordered the tests at four sites. Additionally, we completed a multi-method qualitative assessment using rapid assessment techniques (structured observations, brief surveys, and key informant interviews) to determine the nature of work related to test result follow-up in EHR-based systems at three different sites. Finally, we conducted a socio-technical risk assessment using fault trees to identify key risk determinants that impact EHR-based test result follow-up.

Results: We found clinical workflow and EHRs as main barriers. In clinical workflow there is a need for dedicated personnel for lab results follow-up. In EHRs there is a need for decreasing alert load, implementing EHR designs to facilitate follow-up, and improving patient engagement.

Key Words: health information technology; medical informatics

3. Purpose

The goal of this proposal was to understand the basic science of missed test results.

Our specific aims were:
Aim 1: To understand the cognitive factors that affect the task of test result follow-up by individuals and teams in EHR-based health systems

Aim 2: To understand the nature of clinical work related to EHR-based test result follow-up in the sociotechnical context of health IT enabled outpatient settings

Aim 3: To conduct prospective risk assessments to characterize socio-technical contextual factors that present risks to appropriateness and timeliness of abnormal test result follow-up in EHR-enabled healthcare systems

4. Scope

Background: Diagnostic errors (missed, delayed, or wrong diagnosis) are major contributors to harmful outcomes in outpatients.(1-10) These errors are expensive(11, 12) and are the leading cause of ambulatory malpractice claims.(11, 13-15) A large number of diagnostic errors relate to failure to follow-up on abnormal test results ("missed" test results).(16) The importance of missed test results was highlighted by the American Medical Association report *Research in Ambulatory Patient Safety, 2000-2010: A 10-year Review*.(17, 18) The report suggested that "we still know very little about patient safety in the ambulatory setting, and next to nothing about how to improve it" and specifically highlighted the importance of both diagnostic errors and test result communication failures.

The Joint Commission prioritized safe communication of critical (i.e., acutely life-threatening) diagnostic test results by introducing a National Patient Safety Goal in 2005.(19)

Understandably, most attention has focused on these critical test results.(20, 21) However, research highlights communication failures along the entire spectrum of test result abnormality and severity.(7, 22-26) Emerging literature suggests that the definition of "critical" should include equally important but less time-sensitive "vital" values.(27-30) For example, a chest X-ray with a shadow suspicious for cancer carries the potential for harmful outcomes if missed or if follow-up is delayed. Other types of test results, unrelated to cancer, also have relatively short-term implications for changes in diagnosis or treatment (e.g., newly elevated thyroid stimulating hormone level).(31) However, these types of results are seldom communicated verbally to providers but rather are transmitted by means of indirect, or asynchronous, communication such as electronic health record (EHR)-based messaging, text messaging, mail and secure fax.(32, 33) As compared to verbal notification, these less direct methods of communication may increase the risk of missed test results.(3) Improving follow-up of "non-immediately life threatening" test results is imperative to improving quality and safety of care in the outpatient setting.

Context: Current test result management practices are varied and unsystematic.(24) A literature review summarized 19 studies that documented the frequency and impact of missed abnormal test results for ambulatory patients.(34) The authors reported wide variation in the proportion of abnormal tests not followed up: 6.8% (79/1163) to 62% (125/202) for laboratory tests and 1.0% (4/395) to 35.7% (45/126) for imaging tests. Patient outcomes from missed results included both immediate adverse health changes and missed cancer diagnoses. Test management practices varied between settings, with many individuals involved in the process. The studies documented few guidelines to establish responsibility for patient notification and follow-up. Although evidence of the effectiveness of electronic test management systems was limited, a general trend towards improved test result follow-up in EHR-based systems was apparent. A landmark study in 2009 performed in non-VA settings reported that the rate of failure to inform patients of abnormal results or document having done so was about 7%;(24) use of simple processes for managing results was associated with lower failure rates.

Settings: An academic medical center, a large not-for-profit health system, and a large, complex, comprehensive private integrated health care delivery system.

Participants: Interviews were conducted with a variety of personnel, including leadership, laboratory staff, radiology and imaging staff, radiologists, IT personnel, quality and safety staff, and primary care providers.

Incidence/Prevalence: EHRs can help ensure reliable delivery of important clinical information,(5) but they do not guarantee that this results in appropriate follow-up action. In one study, 36% of abnormal test results transmitted through commercial EHRs did not have documented follow-up.(35) Our own work in the Veterans Health Administration (VA) revealed that almost 8% of abnormal outpatient test results transmitted as EHR-based asynchronous alerts lacked follow-up at 4 weeks.(3, 36)

5. Methods

Study Design

Aim 1

We conducted a mixed-methods study involving three steps. In Step 1 we conducted retrospective medical record reviews to identify rates of abnormal test results with and without timely follow-up at each site. In Step 2 we assessed potential measures of "alert fatigue" within the EHR. In Step 3 we conducted a contextual inquiry on 30 provider interviews.

Aim 2
We conducted this aim in three main steps: 1) Usability analysis of EHR-based test result notification system through cognitive walkthroughs 2) Fact finding to create a "work system map"(37) of socio-technical determinants that influence EHR-based test result notification, and 3) Identify key contextual factors for safe and effective test results follow-up using rapid assessment techniques (structured observations, brief surveys, and key informant interviews). Differences between sites provide insights about determinants within and outside the EHR itself that influence test result follow-up outcomes across institutions.

Aim 3
Using our cognitive walkthrough, work system maps, information obtained through rapid assessment, and other data gathered in Aims 1 and 2, we evaluated the hazard potential for errors at each step in the EHR test result follow-up process and isolated failures that might increase this potential. To create a fault tree for the test result follow-up process, we analyzed interviews from the providers that were given examples from their history. Two researchers independently identified specific instances where the process failed that eventually led to a failure to follow up a test result. Once all factors were identified, the researchers consolidated and divided the individual factors into categories. The factors and categories were then assembled to create a fault tree for the lab result follow-up process.

Data Sources/Collection
Aim 1
We recruited primary care physicians from multiple family medicine outpatient clinics site in Houston, TX. We queried the site's clinical data repository from January 1st, 2015 to September 30th, 2015 to identify potential delays in abnormal results follow-up for ten common imaging, laboratory and pathology tests (e.g., Hemoglobin, Thyroid-Stimulating Hormones, Chest X-Ray, PAP Smears) within patient charts.

Aim 2
We performed a workflow analysis of test result communication by interviewing individuals directly or indirectly involved in the total testing process (TTP) at three large EHR-enabled health care organizations. We thus interviewed diagnostic (i.e., lab and radiology) clinicians and staff, clinic providers and staff, clinic leadership, EHR-related information technology staff, and quality and safety personnel. We identified all TTP steps performed from clinician test ordering to result communication to patients. Findings from all sites were combined to develop a detailed process map of known TTP activities. We additionally asked experts about factors that positively or negatively impacted TTP resiliency at each step. We describe the specific TTP steps identified and associated barriers and facilitators to TTP resiliency.
In another project which evaluated safety huddles to proactively identify and address electronic health record safety, data were obtained from daily safety huddle briefing notes recorded at a single midsized tertiary-care hospital in the United States over 1 year. Huddles were attended by key administrative, clinical, and information technology staff.

Aim 3
We utilized data from interviews conducted earlier in this project to create the test result follow-up process fault trees. The 15 interviews analyzed were those from the providers that were given examples from their own history. We analyzed the selected interviews because they contained first-hand accounts of the process instead of hypothetical situations.

Interventions
None

Measures

In **Aim 1** we reviewed 30 cases of missed follow-up test results and interviewed the providers on those cases. Critical decision method interviews were conducted and contextual inquiry flow models were developed.

In **Aim 2** we interviewed experts at three large EHR-enabled health care organizations and identified all TTP steps performed from clinician test ordering to result communication to patients. Findings from all sites were combined to develop a detailed process map of known TTP activities. We additionally asked experts about factors that positively or negatively impacted TTP resiliency at each step.

We also conducted a content analysis of huddle notes to identify what EHR-related safety concerns were discussed. We expanded a previously developed EHR-related error taxonomy to categorize types of EHR-related safety concerns recorded in the notes.

In **Aim 3** the measures for the fault tree analysis were the specific actions described by the participant that eventually led to a failure to follow-up on a test result. These actions were either errors in the follow-up process or barriers to successfully completing the process. These factors were singled out and gathered to create a fault tree for the process.

Limitations

Aim 1

It is possible that some providers were not forthright about their roles in missed test results, despite our emphasis on confidentiality and a “no blame” approach. In such cases, we were still able to acquire valuable information about many aspects of the case.

It is also possible that a provider’s memory of the case may be inaccurate despite our efforts to identify recent events. Having the EHR documentation available will help cue recall, but this too may not prompt recall of all the important events in the case. To assess the quality of the provider’s account, we evaluated for congruence with other documentation in the EHR and with other staff members’ accounts, when applicable. Additionally, the preparatory chart reviews and the post-interview analysis involved physician experts, including those familiar with the workings of these facilities, which helped detect incongruent or unrealistic elements in an account.

Aim 2

The cognitive walkthrough method included how clinical content interacts with the user interface, but it did not incorporate the role of interruptions or other social environment factors. Similarly, cognitive walkthroughs did not incorporate any non-standard procedures (e.g., “work around” techniques) or strategies developed by providers to manage alert overload.

Aim 3

Our model might not be able to explain all differences in outcomes and may not be able to establish causal relationships. Respondents’ recollections also may be biased in certain ways. For example, they may only recall the most recent events they experienced or witnessed (recall bias), which may lead them to say these are also the most significant.

6. Results

Principal Findings

Aim 1

Variation in EHR Implementations

We found all 8 dimensions of the socio-technical framework to be relevant for ensuring follow-up of abnormal test results. The technology-related dimensions (hardware and software, clinical content and user interface) included specific factors that could contribute to lack of timely follow-up, such as inability to share information across the systems, inability for patients to access electronic results, lack of prioritization of alerts by the EHRs, lack of multiple patient views in the display, lack of functionalities for task coordination among team members and lack of user-centered design in the EHR. The dimensions related to internal and external environment (internal organizational policies, procedures and culture and external environment) included factors such as inflexible internal organizational policies for test results follow-up, difficulties in delegating responsibilities within the organization and difficulty in external care coordination with outside providers. Clinical staff shortage ("personnel" dimension) was also seen to be a contributing factor. Moreover, we found that overall the rationale for delays in follow-up was more significantly related to the "clinician's workflow" dimension. Factors such as excessive ordering of unnecessary tests, time constraints to deal with delayed results, difficulty in notifying patients, unique patient's conditions requiring different prioritizations (such as very sick patients requiring more attention) and lack of standardized workflow processes (such as personalized work arounds to deal with follow-up) contributed to missed abnormal test results follow-up due to variations in clinician's workflow.

Contextual Inquiry

Through contextual inquiry, we found that breakdowns can occur in several steps throughout the process. In the cases where providers were given examples of their own cases, the breakdowns were more often attributed to workflow issues such as issues related to the delegation of following up or that no treatment modifications were necessary, so no follow up was taken. However, in the cases where providers were given examples not based on their own history, the breakdowns were more often attributed to technological issues such as patient access to the patient portal to view the result or an automatic release of the result to the patient after a period of time, imposed by the EHR.

Impact of a National QI Program

In a project assessing the impact of a national QI program on reducing electronic health record notifications to clinicians, we found that based on prior estimates on time to process notifications, a national QI program potentially saved 1.5 hours per week per PCP to enable higher value work. The number of daily notifications remained high, suggesting the need for additional multifaceted interventions and protected clinical time to help manage them. Nevertheless, our project suggests feasibility of using large-scale 'de-implementation' interventions to reduce unintended safety or efficiency consequences of well-intended electronic communication systems.

Electronic Health Record Alert-Related Workload

In another related project evaluating EHR alerts as a predictor of burnout in primary care providers our results showed that burnout associated with alert workload may be in part due to subjective differences at an individual level, and not solely a function of the objective work environment. This suggests the need for both individual and organizational-level interventions to improve alert workload and subsequent burnout. Additional research should confirm these findings in larger, more representative samples.

Aim 2

Process Maps

We interviewed a total of 39 individuals: 14 at Site A, 8 at Site B, and 17 at Site C. Participants included 13 primary care physicians and staff, 13 laboratory and radiology representatives, 6 clinic administrators, 1 patient safety personnel, and 6 informatics and information technology personnel.

Process Mapping

Using process mapping methods,(38) we developed individual process maps for each site based on input from interviews. Each process map was used to identify specific facilitators and barriers at each step. The three site-specific process maps were then merged into a single process map encompassing all common TTP steps (Figure 1). To facilitate reporting of facilitators and barriers, we further divided the pre-analytic, analytic, and post-analytic phases of diagnostic testing into the following TTP major activities based on prior work on the testing process:(39) (1) EHR-based test ordering, (2) transmission of orders to diagnostic service, (3) test scheduling, (4) sample collection/image acquisition and transportation, (5) sample/image processing and interpretation, (6) report transmission, (7) clinician review and interpretation, and (7) patient-clinician discussion and care planning.

Of the eight major activities, substantial differences were seen across sites for order and report transmission. For the order transmission, clinics relied on either transmission of electronic EHR-based test orders that would be printed at the diagnostic site, printing of order at the clinic for the patient to hand carry to the diagnostic center, electronically-transmitted orders, or a combination of all three depending on the specific test and whether it would be done immediately or in the future. For the report transmission, clinicians communicated test results directly to patients via phone or patient portals, generated letters with test results and interpretations, or relayed messages to staff members to call patients with results. All sites used a mix of these methods depending on the result urgency and whether the patient's status on the patient portal was active. The remaining activities were similar across sites.

TTP Barriers and Facilitators

On the TTP activity inventory, barriers and facilitators of the test result process were notated with process step that they impacted. Barriers identified were seen throughout the process, but were most heavily concentrated in the interfaces between clinics and testing services as well as between clinicians and the EHR. Barriers identified were related to technology and usability issues, time and resource constraints, suboptimal clinic workflows, patient-related factors, information access limitations, and insufficient clinician training. Details about specific barriers and facilitators are described below.

Pre-Analytic Phase

1. EHR-based Test ordering

Participants reported usability barriers related to identifying the correct and intended test orders among lists of similar alternatives in the EHR (e.g., "CBC," "CBC w MVP," "CBC w/o DIFF w PLT," "CBC (aka OBSTRETIC PANEL)" and "CBC (DO NOT ORDER)"). Participants reported that choosing an incorrect order sometimes led to a test other than the intended one being performed. However, physicians indicated that use of personal and clinic-level order preference lists helped facilitate and streamline choosing of appropriate tests. Additionally, they reported that use of standardized conventions for naming orders in the EHR improved the ability to choose the intended order by reducing ambiguity of which test would be performed. Laboratory and radiology personnel indicated that physician knowledge gaps related to which tests to order in certain situations additionally lead to incorrect test ordering, which requires radiologists or

technicians to contact physicians to clarify orders. For example, radiology technicians reported needing to contact physicians when contrast-based studies were required for specific symptoms, but non-contrast studies were ordered, resulting in delayed or canceled testing. One site reported that an online guide for ordering imaging tests based on expected diagnosis or symptoms has reduced the number of calls to physicians to clarify orders.

2. Transmission of test orders to diagnostic service
No site used electronic orders exclusively, and participants reported that printed orders were required in some or most instances depending on the site and test. Participants reported that this introduced opportunities for printer-related technical difficulties, for providing patients with incorrect orders (e.g., due to orders for other patients simultaneously sitting in the printer), for incomplete testing (e.g., not all pages of orders printed, provided to patients, or arrive at lab), and for testing to be performed at incorrect times (e.g., patient delivers all orders to a laboratory when a portion of orders were intended to be performed at a future date).

3. Test scheduling
Participants reported that barriers to scheduling patients for testing included difficulty reaching patients. However, practices to collect multiple methods of contact (e.g., multiple phone numbers or patient portal access to facilitate electronic messages) as well as offering walk-in visits for certain tests (lab and plain imaging) helped to facilitate the scheduling process, particularly for same-day testing.

4. Sample collection/Image acquisition
Participants reported that patients failing to show or refusing tests due to unexpected costs and insurance coverage served as a barrier to both laboratory and radiology testing. Additionally, tissue samples that were transported long distances to reach the laboratory were reported to possess a higher likelihood of lab artifact.

Analytic Phase
5. Sample/Image processing
Laboratory and radiology personnel reported no significant barriers to the testing process once the lab was drawn or radiology image acquired and was undergoing interpretation. However, participants indicated that use of standardized policies to review test result anomalies (e.g., critical results or an unusual series of abnormal results) and orders without results within a typical timeframe helped to reduce processing errors by allowing investigation into delays or incorrect processing and enable retesting, if necessary.

Post-Analytic Phase
6. Report transmission to clinician
Other than testing performed at locations unaffiliated with the physician, which were transmitted via fax, most results were transmitted electronically from the laboratory or imaging site. Participants indicated that robust interface between the diagnostic testing center and the physician's EHR greatly improved transmission of results as compared to faxing, which suffered from routing, technical, and legibility issues and often required a dedicated staff member, such as a medical secretary, to effectively manage. Routing issues were also attributed to problems connecting medical resident-ordered labs to the supervising attending when the resident was not present in clinic (e.g., on vacation or a different rotation). Physicians also reported routing problems when the ordering physician's name was incorrectly transcribed by the lab, leading to potentially routing results to the incorrect physician. Conversely, use of an "out of office" feature to forward result to the appropriate covering physician when the ordering physician was absent

or other method to cover other physician's EHR-based inboxes prevented breakdowns in care when physicians were unavailable.

7. Clinician review and interpretation of results
Physicians reported several barriers related to processing of results, including overload from numerous other messages, lack of a method to distinguish abnormal from normal results in the inbox for some results, interruptive environments, lack of training on sorting and filtering features, and need to open images in a separate program rather than the EHR, which added to the time needed to properly process messages. Physicians report that features enabling rapid review and release of results and interpretations, access via a health exchange to results done at other institutions, and availability of care coordinators to track follow up of certain high-risk results (e.g., positive fecal occult blood tests for cancer screening) greatly improved interpretation of results.

8. Patient-clinician discussion of results
Communication of results and expected follow-up actions had the largest amount of flexibility both within and between facilities and depended on whether follow-up action was needed, whether patients were signed up to the patient portal, and whether nursing staff participated in the communication process. Physicians reported that two large barriers to communication included not having correct patient contact information when making phone calls and poor use of the patient portal system. Conversely, physicians reported that an EHR-based self-reminder system greatly helped them to ensure that appropriate action was taken (e.g., a reminder to check a patient's chart in 3 days to ensure the patient visited the lab to repeat high potassium). Physicians reported that features to streamline release of results (e.g., templated letters or quick methods to release results to the patient portal) greatly streamlined communication, allowing them to spend time on medical decision-making.

Graphical Display of Diagnostic Test Results
In a study evaluating graphical display of diagnostic test results in EHRs across eight systems, we evaluated the displays using eleven objective criteria for optimal graphs and found that none of the EHRs met all eleven criteria. The magnitude of deficiency ranged from one EHR meeting 10 of 11 criteria to three EHRs meeting only 5 of 11 criteria. Our study suggests that many current EHR-generated graphs do not meet evidence-based criteria aimed at improving laboratory data comprehension.

Safety Huddles
From 249 safety huddle reports, we identified 3,270 safety concerns (mean: 13/day). Of these, 245 (7%) were EHR-related safety concerns; note that these were beyond just test results related. The proportion of EHR-related safety concerns was higher in the go-live stage (first three months: 12.6%), but remained constant at about 7% in the final three months.

We classified EHR-related safety concerns into six of eight sociotechnical dimensions; two dimensions, "external rules" and "monitoring," were not found relevant for this purpose. The most common error was "EHR technology working incorrectly" (41.6%), followed by issues with the EHR system not working at all (25.7%). Missing or absent EHR technology was associated with 16.7% of reported safety issues. Finally, EHR concerns linked to user errors were linked to the remaining 15.9% of reports.

Of the sociotechnical dimensions, "hardware/software," "clinical content," and "people" accounted for nearly three quarters (74.7%) of all safety issues identified. Most EHR-related issues found were related to the "hardware/software" dimension (80/245, or 32.7%), which

included two subcategories: “hardware malfunction” (9/80) and “software malfunction” (71/80). In breaking down the category further, we determined that errors related to the “loss or delay of data” accounted for four-fifths of all issues within the “hardware/software” dimension (65/80). “Loss or delay of data” included 24 concerns related to errors in data transmission, including failure in transmission of laboratory orders from the laboratory system to the EHR and failure of the EHR to display accurate information. This subcategory also included 11 instances when various aspects of the EHR software, such as results display or order entry, were not available for use.

The “clinical content” dimension accounted for the second largest share of issues (53/245, or 21.6%), and it included errors related to “incorrect/inappropriate reference information” (47/53) and “incorrect/inappropriate charting templates” (6/53). The reference information issues were most likely to be related to erroneous or missing information in the EHR.

The “people” dimension accounted for 20.4% of issues (50/245). These included user errors such as “failure to carry out clinical duties” (11/50), “inattention to detail” (18/50), and “shortcomings in staff qualifications” (10/50). The remaining issues in the “people” dimension resulted from local system administrators following poor system configuration procedures, such as assigning incorrect role-based access privileges to some clinicians.

The remaining quarter of EHR safety issues were related to “workflow and communication” (31/245, or 12.7%), “human-computer interface” (28/245, or 11.4%), and “internal organizational features” (3/245, or 1.2%). “Mismatches between workflow and health IT” were responsible for nearly all issues identified in the “workflow and communication” dimension (29/31). The “human-computer interface” dimension was characterized by concerns with “errors in data display” (18/28) and by “data entry errors” (10/28). The three events classified as concerns in “internal organizational features” included a “policy in conflict with existing clinical workflow” (1/3) and, in two cases, the “absence of a protocol or standard process” (2/3).

Aim 3

Fault tree creation identified several root causes of the breakdown of the test results follow-up process. Many of the factors were clinician related, such as waiting for the next patient visit to follow-up and assuming responsibility for follow-up falls on staff or other providers. Several patient-related factors were found, such as language barriers, patients not using the patient portal, and resistance to making phone calls to patients. Occasionally the breakdown was related to the patient’s clinical condition, such as if there was not an urgent change in care. Finally, there were EHR related breakdowns, such as a lack of alert in EHR that the lab result was ready.

Discussion

Aim 1

A broad range of socio-technical factors may lead to delays in abnormal test result follow-up. Enhancing the design of current EHRs and focusing on a host of sociotechnical factors that we identified may improve follow-up of abnormal test results in outpatient settings. In order to improve patient safety, interventions are needed to address the underlying causes for delays in abnormal test results follow-up.

Contextual inquiry identified several process breakdowns. Three main user groups were identified in the follow-up process – providers, staff, and patients. In future research, the identified process breakdowns can be used to define design requirements for each of these user groups for a lab result/follow-up management system.

Aim 2

Process Maps

We identified pathways involved in the total testing process for both laboratory and imaging testing at three organizations using electronic health records, and characterized key factors that increase the likelihood of process breakdowns and mitigating factors that reduce breakdowns by increasing the robustness of the total testing process. While factors that led to breakdowns were identified at all stages, identified factors most commonly involved pre-analytic and post-analytic stages.

While barriers were seen throughout the testing process, we found the highest concentration, and thus this highest risk of breakdown, at steps that partially or completely involve health information technology. This principally included usability of the EHR by clinicians and communication interfaces between the EHR and diagnostic services. For example, participants reported difficulty in communicating the intended test order to the lab due difficulties selecting appropriate orders in the EHR and incomplete electronic interfaces with lab services, while poor EHR usability related to physicians identifying appropriate orders and electronic routing problems introduced difficulties in transmitting results to and prioritizing results for clinicians. While it is likely that EHRs provide an improvement over the paper-based systems that preceded them, our findings suggest an improved focus on EHR usability and HIT system interoperability are needed.

We identified several facilitators of testing process resiliency involving multiple socio-technical dimensions, including personnel training, workflow optimization and standardization, additional helpful EHR features, and improved electronic communication between clinics and diagnostic services. Several facilitators directly addressed barriers at the same or other study sites. For example, efforts to enroll patients in online portals offered an alternative communication channel when barriers were encountered attempting to communicate with the patient via other channels. Certain facilitators, such a use of walk-in appointments for labs and certain imaging tests to prevent delays related to scheduling difficulties, were presently in use at one or more of the study sites indicating the feasibility of their implementation; however, other factors, such as dedicated care coordinators or direct electronic interfaces between clinic EHRs and the diagnostic services they refer to, may be more difficult or costly to implement. Further study on the direct impact of TTP resilience is needed to help prioritize the implementation of facilitators.

Safety Huddles

Despite calls for greater attention to EHR-related safety risks(40, 41), most HCOs do not have well-developed systems to identify and address EHR-related safety concerns (42). Our analysis of 249 daily safety huddle briefing reports identified 245 (7%) instances of EHR-related safety concerns, suggesting that EHR safety discussions represent a noteworthy proportion of all patient safety discussions within huddles. While direct comparisons might be somewhat limiting, compared with previous studies of EHR-related safety events reported in large databases (43-45), this study found a much higher frequency of EHR-related safety concerns. For example, Magrabi et al. found that only 0.1% of all reports in the FDA (MAUDE) database involved health information technology-related errors. In another study, Magrabi et al. examined reports from a voluntary incident reporting database and found that only 0.2% involved information technology systems. Although incident reporting offers a valuable source of information regarding safety issues, such voluntary reporting systems are likely to underreport the number of actual errors (46). Several factors, such as perceived difficulty in using the system (47), lack of training in the use of the incident reporting process (48), and time required to report errors, can lead to underreporting of safety issues. In our study, safety concerns were communicated verbally during the daily huddle briefings and provided a less burdensome and more conversational

mechanism to discuss sensitive issues. Additionally, incentives attached to the “great catch” program run by the hospital to report “near-miss” safety events, possibly encouraged staff members to report safety issues.

Because raising awareness of EHR-related safety concerns may require collaboration across departments and specialties, institutional safety huddles can be an effective strategy to share information about actual or potential EHR concerns with the entire health care team.

Other HCOs could consider safety huddles as a venue to raise concerns and share information about ongoing EHR safety issues, a process which could also involve the vendors. This could foster greater inter-departmental communication and situational awareness than could be garnered from other current methods, including incident reporting.

Aim 3

The creation of the fault trees led to the discovery of several root causes of follow-up process breakdowns. These root causes should be used in the future to improve processes and make them more resilient to breakdowns. They could also be used as design requirements for the creation of a lab result/follow-up management system.

Conclusions

Aim 1

Real-world EHR implementations are accompanied by several factors that positively or negatively impact the safety of test results follow-up and tracking processes. Understanding these factors can allow for the development of best practices for EHR design, implementation, and use that ensures safer tracking and follow-up of abnormal test results.

Additionally, the identified breakdowns of the test result follow-up process indicate that improved communication and management tools are needed, including better EHR inbox management related practices. The results of the contextual inquiry can be used to inform the future design of a test result follow-up management system. Using the identified major process breakdowns, this system could be better designed to facilitate successful test result follow-up for all potential user groups, leading to better communication and patient care.

Aim 2

Process Map

We identified key pathways involved in the total testing process for both laboratory and imaging testing in EHR-based environments, as well as factors that served as barriers and facilitators to process resilience. Interfaces between clinicians and diagnostic testing sites and usability of the EHR served as key areas where barriers increased the vulnerability of the process and serve as important areas for future efforts to improve process resiliency. Facilitators identified to serve as a basis for future work in their effectiveness at improving the resiliency of the testing process.

Safety Huddles

Our study suggests that the “blame-free” culture created by safety huddles supports open communication between key administrative, clinical, and information technology staff. Safety huddles could potentially serve as an important methodology for institutions to identify, understand, and address the complexity of EHR-related patient safety concerns. Based on our findings, we recommend other health care organizations consider them as a strategy to promote understanding and improvement of EHR safety.

Aim 3
There are several process improvements that can be applied to the test result follow-up process. The root causes of the breakdowns can be used to improve these processes and make them more resilient.

Significance:
Delayed diagnoses resulting from test result communication failures is an important topic and a significant problem. This study sought to understand the basic science of missed test results. Given the absence of national guidance, findings from this study could be useful for strengthening policy and practice in this area.

Implications:
The information gained by carrying out this study will lay the groundwork for future work to reduce delayed diagnoses due to missed test results. There are overwhelming benefits from improving test result communication via EHRs in terms of preventing delayed diagnoses.

7. List of Publications and Products

Published:

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