Title of Project: EHR solutions for accurate reporting of data on interprofessional ICU rounds

Principal Investigator: Jeffrey A. Gold

Co-Investigators: Vishnu Mohan, Judith Baggs, David Bearden, Deborah Eldridge, Joan Ash

Organization: Oregon Health & Science University

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Federal Project Officer: Mario Teran

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1. Structured Abstract:

Purpose: To use simulation to understand the role the EHR plays in appropriate gathering and reporting of patient data on interprofessional ICU rounds.

Scope: ICUs comprise the highest resource utilization area in a hospital. One hallmark of ICUs is their high degree of data density, with nearly 1800 data points/patient/day. Managing this data density is essential for the delivery of safe and efficient care. Interprofessional rounds are an essential tool that can improve communication and reduce errors within the ICU. However, a major barrier to conducting effective Interprofessional rounds is efficient and accurate gathering of information, specifically through EHRs. This is exacerbated by the observation that each profession has different workflows in respect to the EHR and thus has access to different data for each patient.

Methods: We used a combination of survey methodology and real-world audits of ICU rounds to determine which data elements are at risk for failed extraction and communication from the EHR. High-fidelity Interprofessional rounding simulations, with structured EHR charts were used to provide a test-bed to develop novel solutions.

Results: A massive amount of data are omitted from rounding presentations and this is dependent on EHR use patterns. When validated in a controlled, high-fidelity rounding simulation, it demonstrated the significant impact this has on clinical decision making and highlights the role it plays in variance in care delivery. Automation of data importation into rounding tools to eliminate blindspots had little impact on this highlighting the need for realtime simultaneous data gathering to improve communication.

Key Words: Rounds, ICU, EHR, Simulation, Patient Safety

2. Purpose:

Intensive care units (ICU) comprise the highest resource utilization area in a hospital. One hallmark of ICUs is their high degree of data density, with nearly 1800 data points/patient/day. Managing this data density is essential for the delivery of safe and efficient care. Interprofessional (IP) rounds are an essential tool that can improve communication and reduce errors within the ICU. However, a major barrier to conducting effective IP rounds is efficient and accurate gathering of information, specifically through EHRs. This is exacerbated by the observation that each profession has different workflows in respect to the EHR and thus has access to different data for each patient. We hypothesize that a large number of data communication errors exist across all data domains and for all professional groups in IP ICU rounds. By using a multimodal approach and a series of toolboxes to standardize and optimize data retrieval from the EHR, we can ensure accurate and effective data communication during rounds and reduce the incidence of these data communication errors. In **Aim #1** we performed a comprehensive audit of ICU rounds to determine the data domains at greatest risk for communication errors, and the role the EHR and clinical users play in the genesis of these errors. We also conducted a national survey to determine which data domains should be examined and how data should be communicated between ICU IP rounding team members. These data were used to create a series of high complexity use cases for an EHR centered IP ICU rounds simulation in **Aim #2**. These simulations recreated currently existing data communication errors and establish baseline usability metrics by incorporating eye and screen tracking to study and analyze team member interaction with the EHR before and during rounds. In **Aim #3**, we used data from Aims #1 and #2 to create a series of toolboxes to facilitate the creation of EHR generated rounding tools, either for standard IP ICU rounds or a series of screens for an EHR-centric ICU rounding structure that allows for synchronous, real-time viewing of data by all members of the IP team. Toolboxes were tested in our simulation environment to ensure their ability to improve the veracity of communicated data without having negative unintended consequences on team communication, workflow efficiency or EHR usability.

3. Scope:

Background/Context: Electronic health records (EHRs) have been in use since the 1960s, but only in the last decade has their potential for improving the quality and safety of health care been recognized and promoted. This led to the passage of the Health Information Technology for Clinical and Economic Health (HITECH) which provided financial incentives for EHR adoption and “meaningful use”. The rationale behind these incentives were the purported significant benefits of EHRs, including improved patient safety, greater portability of health records and the ability to reduce costs associated with healthcare delivery. Within the incentive program, providers and organizations receive bonuses if they meet specified EHR meaningful use criteria in an escalating fashion, with eventual financial penalties for failure to meet these criteria. Spurred by HITECH, EHR adoption rates have increased dramatically.

The potential for EHRs to improve patient safety came to light in 1999, when the Institute of Medicine (IOM) published the report, "To Err is Human”. This report, with the subsequent 100,000 Lives Campaign of the Institute for Healthcare Improvement (IHI), suggested that systems designed to improve patient safety should be at the forefront of medical care. With a concomitant stimulus for research, a number of studies were published in the ensuing years suggesting that health IT, including Computerized Order Entry (CPOE) and inclusive EHRs could significantly improve patient safety resulting in a net reduction in preventable errors. Specifically, as CPOE became more widely available, a number of studies demonstrated that CPOE could reduce a wide variety of medication errors and adverse drug events. This was associated with a significant rise in EHR use across the country, with a near tripling in the number of hospitals using any form of EHR during the first decade of the 21st century.

With the increasing trend towards universal adoption of EHRs, concerns that there could be a multitude of unintended consequences associated with their implementation arose, with some trepidation that these unintended consequences may cancel out any perceived benefits associated with their use, and even actively cause patient harm, which has been described as "e-iatrogensis". One example of harm induced by the implementation of an EHR was documented by Han et al, where the introduction of a commercial EHR in a neonatal ICU was associated with increased all-cause mortality. While initially the system itself was implicated in the negative outcome, subsequent research demonstrated that this incidence of e-iatrogenesis was not due to the system itself, but rather due to inferior implementation of the system, lack of customization, and suboptimal education and training, particularly with respect to utilization of the EHR by clinicians. This assessment was supported by a subsequent study documenting improved outcomes with implementation of an identical system in a similar clinical setting. A similar experience was observed at The Ohio State University where enterprise-wide implementation of their EHR proved successful throughout the medical center, except in the Medical Intensive Care Unit (MICU). In this specific clinical setting, problems related to poor training, inadequacies in the EHR-physician interface and lack of customization created unmanageable workflow issues and the system was taken off-line within 6 months after implementation. The system would be reintroduced back into the MICU only after a number of changes with respect to improved customization, increasing the number of available computers and improved training and education. Interestingly, both of these reports of poor implementation of EHRs occurred in ICUs.

The ICU is perhaps one of the most unique environments in the spectrum of health care delivery. While overall U.S. hospital bed occupancy has consistently decreased over the last 20 years, the proportion of hospital beds dedicated to ICU medicine and overall ICU bed occupancy has significantly increased. As a result, ICUs continue to use a greater and growing proportion of health care resources, with a near 44% increase in health care costs between 2000-05. ICU medicine now accounts for nearly 14% of U.S. hospital care costs and nearly 1% of total U.S. GDP.

As previously mentioned, one of the first environments to exhibit problems associated with poor EHR implementation and/or use was the ICU. While the etiology of complex system malfunction is typically multifactorial, one significant contributing factor in the ICU setting is the sheer amount of data generated during routine patient care. A recent study revealed that the average ICU patient generates nearly 1400 data points/patient/day, with some patients, such as those also requiring renal replacement therapy, generating close to 2000 data points/day. Assuming an average ICU census of 15 patients, a perceived threshold for safety, this would generate nearly 20,000 data points/day. Given that the average ICU length of stay (LOS), especially for those with septic shock and ARDS can approach 7-10 days, these data points generated every day must not only be considered by themselves, but also contextually with both ante and postcedent data points in a relevant temporal sequence. Successful use of an EHR is dependent upon providers being able to efficiently navigate and integrate these data points and trends. Further, the high degree of acuity of the average ICU patient often results in the need to make a large number of decisions in a short timeframe juxtaposed with the need to rapidly process a large influx of large amounts of information, often in real-time. Consequently, it is easy to envision how problems with data fragmentation and poor user-interfaces can lead to significant issues with clinical cognition and pursuant errors. This was confirmed in our prior study, here residents and ICU fellows were only able to recognize 40% of relevant patient safety issues in an EHR based ICU simulation exercise. This issue is compounded by the fact that the large number of the data points generated in the ICU can trigger frequent alerts within the EHR. For example, studies suggest that between 59-96% of warnings generated during computerized medication order entry are ignored or overridden by clinicians. Similarly, ICUs have a large number of alerts generated within the EHR, many of which are due to abnormal lab values and physiologic parameters.

The other issue is the significant interprofessional (IP) nature of ICU care. Workflows in the ICU are highly dependent on healthcare delivery performed by a robust IP care team. It is currently standard of care for an ICU team to comprise of physicians, nurse, pharmacists, respiratory therapist, nutritionist and often physician extenders (such as physician assistants and/or nurse practioners). At academic medical centers, the team grows to include trainees in all of these professions. This has significant implication for optimizing EHR utilization as each profession has different workflows and utilizes the EHR differently, often using individually customized interfaces. As a consequence, the documentation generated by different members of the ICU team can be discordant; one study noted that there was less than 40% agreement between nursing and physician documentation within the EHR and overall, physician and nursing views of the usability of the EHR and impact the EHR has on daily workflow appears to be significantly different. Further, the EHR is often used as a communication tool in of itself, which can have unintended consequences on IP communication. This issue was highlighted in a study where CPOE implementation in an ICU, while in theory establishing a simple linear path of communication from physician order entry to pharmacist to unit clerk to nurses, resulted in an extremely convoluted process that hindered rather than fostered communication and resulted in an increased number of phone calls and a consequent impairment in efficiency. These extra elements of verbal communication can actually further compound errors. In one study, frequent interruptions of physicians when using the EHR on rounds led to problems with fragmentation, which further impaired efficiency and led to the generation of additional errors.

Because of the complexity of clinical care in the ICU, the sheer volume of data generated, and the number of different professions involved in the delivery of care of each patient, optimizing provider communication is essential. The common tool used by all clinicians during patient care is the EHR, and thus places the EHR at the nexus for the majority of data communicated in the ICU. The EHR, if used efficiently and in an optimal fashion, has the ability to provide all members of the ICU team with appropriate data that allows them to engage in superior clinical decision-making, and to foster effective and accurate communication of data between team members. Conversely, reducing or eliminating sub-optimal data utilization will allow improvements in patient care as well as safety.

In studies conducted in diverse clinical settings, poor communication between members of the IP care team is a major source of medical errors, leading to both morbidity and mortality. The main period for data communication between all members of the IP team in the ICU is daily rounds. The purpose of rounds is to review all relevant information since the prior instance of rounds with data presented from all members of the team. These data are then integrated and utilized to determine the daily care plan, as well as to codify the implementation strategy to ensure the plan is carried out appropriately. However, the quality of that plan is directly related to the integrity, accuracy and veracity of the data presented. Indeed, cognitive errors and errors in medical decision making are believed to be the largest class of medical errors for non-procedural areas. These errors are frequently driven by a number of cognitive biases that influence clinical decision making. Examples include anchoring bias, framing effects and diagnostic momentum. Many cognitive biases are influenced by the data available (availability bias) to the clinician (or not), and the visualization of data at an appropriate time during decision-making, this again placing the EHR at the nexus of the issue.

Historically, clinicians providing patient care rounded in groups determined by their profession. Interprofessional rounds were instituted to try and improve the quality of the daily rounds, by including multi-professional participation and shared decision making. In the ICU, these rounds typically include participation by the bedside nurse (RN), pharmacist, respiratory therapist and nutritionist (if present), in addition to physicians and/or physician extenders. Interprofessional rounds are routinely scripted to optimize time efficiency during rounding. When conducted in this fashion studies suggest that the use

of IP rounds can significantly improve communication and reduce medical errors. **Therefore, the hypothesis for this proposal is that there are a large number of data domains which are miscommunicated by all members of the IP team during ICU rounds. These data communication errors can be dramatically reduced by developing a series of standards for both EHR generated rounding tools for all members of the IP rounding team, and standards for real-time integration of the EHR into IP ICU rounds for synchronous data review.**

Settings: All studies took place in a Medical Intensive Care Unit at an academic medical center.

Participants: All members of the interprofessional team in the Medical Intensive Care including physicians, nurses and pharmacists. Physicians include members of all levels of training.

4. Methods:

The methods for this protocol are subcatagorized in 3 specific Aims, each with their own indepdent methods and findings.

Specific Aim #1: Determine frequency of, and factors responsible for, data communication errors during IP ICU rounds

Specific Aim #1A: Determine the frequency of data communication errors during IP ICU Rounds.

Studies took place in the OHSU MICU. On random days, rounds were audio-recorded by a member of the study team. In addition, we collected the average daily patient census and the temporal sequencing of the patient presentation (i.e. whether the patient was presented early or late during rounds). At the conclusion of rounds, we collected the rounding tools used by the physician, RN and pharmacist. They were copied, deidentified and originals immediately returned to the respective provider.

For analysis, all audio recordings were transcribed, and transcripts reviewed were compared with the data communicated verbally and with the actual data in the EHR at the time of presentation (as determined by date and time stamp). Given that current standards suggest the purpose of daily rounds is to discuss the patient's clinical condition and facilitate team-based decision making informed by all data generated since the prior day, we considered all data that resulted since rounds the day before eligible for analysis. Misrepresentations were further classified by the clinical role of the presenter (MD vs. RN vs. pharmacist).

For analysis of the rounding tools we performed a document analysis to first identify the different types of tools created by clinicians. This includes whether it is human (hand written or typed by hand) or computer generated (with data elements auto-populated from the EHR utilizing templating) and if EHR generated, whether an individualized rounding tool was used, or whether the clinician adapted the default daily progress note as the template for the rounding tool. Next, to better understand the contribution of the artifact to the information misrepresentation, we compared the data verbalized by the subject, with: 1. the data present in the rounding tool and 2. the data present in the EHR, with the EHR data representing the gold standard. This was done for each clinical role based on the data verbalized by the subject during their presentation. Finally we determined whether the source of the error was in the creation of the tool itself (for example, data omitted from the presentation were not documented or incorrectly represented on the tool), or whether the error lay in the interpretation of data available to the subject within the tool (for example, data were correctly present on the tool but incorrectly verbalized by the subject).

Specific Aim #1B: Conduct a formal, local and national needs assessment for information communication during IP ICU rounds.

To understand the information needs in the EHR, we created a survey which addressed four domains: 1. What information should ideally be presented during IP rounds by each clinician (organized by their role), 2. What the current perception by survey subjects regarding the role of the EHR during rounds, 3. What types of errors have occurred during IP rounds which, in the opinion of survey subjects, is secondary to EHR design or usability, and 4. What strategies are used by survey subjects to prepare for rounds. The survey was distributed electronically via REDCap both locally and nationally through the Society for Critical Care Medicine.

Specific Aim #2: Creating of Controlled Interprofession ICU Rounding Simulation.

Using data from Aim #1, we created a series of high-fidelity EHR cases as the backbone of the simulation. These cases contained data elements employed by pjhysician, nurses and pharamcists. Further, all cases contained at least 4 days of data to mimic average complexity. Cases were desgined to assess effective data extraction and decision making such they contained at least one high risk data element within each of the major data domains (as defined by Aim #1), a built-in clinical decompensation scenario which requires either trending of data or linking data from different domains in order to successfully avoid an adverse clinical event and at least one simulation feature that demonstrates a deviation from adherence to ICU best practice.

Cases were initially validated for each professional group individually (multiprofessional) to ensure adequate validate and performance characteristics and that the orientation to the case (e.g. pre-rounding routine) was consistent with each professional group's workflow. Once completed, we created a full interprofessional simulation based on the ICU set rounding script. Each simulation was graded across 3 domains: Effective Use- as defined by the ability of team members to identify clinical decompensations, Teamwork and Communication- as defined by standardized communication evaluation tools and EHR Usability- as defined by the incorporation of eye tracking into EHR navigation and associated EHR use characteristics with the other two domains.

Specific Aim #3: Develop and test standardized methods for Interprofessional data collection and presentation for ICU Rounds.

We used the ICU rounding simulation to test two primary modes of improving data communication on rounds. Method 1 is one dependent on Sequential Data Assimilation and Dissemination (SDAD). In this model, we created better tools for individual professional groups to collect data prior to rounds (akin to currrent workflow). Based on results from prior Aims this was implemented through the creation of note templates which automatically imported data elements most likely to be ommitted on rounds. We used simulations to test the usability of these as above and then, used a real world experiment to test their effectiveness. All interns, as part of onboarding, underwent EHR simulation training on effective navigation of the EHR and specifcally focused on ICU note writing and incorporation of the the new templates. We then audited all progress notes in the ICU for adoption of the new templates and then used rounding audits (as described in Aim #1) to determine the impact on data communication.

The second model is one of Real Time Data Assimilation and Dissemination (RDAD). For this we created a novel rounding computer which allows for simulatenous visualization of the EHR by all three professional groups, yet allowing for individual workflow. This protoype underwent initial concept validation with our ICU rounding simulation followed by two rounds of beta testing. In order to facilitate use of the system, an ideal pattern for shared EHR navigation was developed through strucutred survey of members of the ICU team to determine screens associated with highest yield. This script was then

validated with an additional round of simulation. All simulations were scored for usuability, as determined by System Usability Scale, and Eye-Tracking.

5. Results:

Note, due to the separate nature of each Aim, results are subdivided into the individual specific aims. Each section will contain its own brief discussion and conclusion.

Specifically, for Aim #1A, "Determine the frequency of data communication errors during IP ICU Rounds". Our first manuscript was published in Critical Care Medicine which demonstrated a high frequency of laboratory data omitted from rounds and that the biggest predictor of data omission errors was the methodology used by the residents to gather information for rounds AND the frequency in which specific lab values were ordered in the ICU. This implying less frequently ordered labs were more likely to experience reporting errors. This paper is currently still in the 93rd %tile in terms of impact. We expanded upon this methodology to characterize the frequency of data omission errors across ALL data domains in the ICU using audio recordings of rounds. Our primary results were obtained during an audit of 157 patient presentations including 6,055 data elements across nine domains revealed 100% of presentations contained omissions. Overall, 22.9% of data were missing from artifacts and 42.4% from presentations. The interprofessional team supplemented only 4.1% of additional available data. Frequency of trainee data omission varied by data type and sociotechnical factors. The strongest predictor of trainee verbal omissions was a preceding failure to include the data on the artifact. Passive data gathering via electronic health record macros resulted in extremely complete artifacts but paradoxically predicted greater likelihood of verbal omission when compared with manual notation. Specifically, when data is only populated through the use of prebuilt macros, it is only presented successfully 50% of the time. However, if there is any component of manual (either typing or writing) of the data, this is associated with almost 95% success rate in presentation. Finally, interns verbally omitted the most data, whereas medical students omitted the least. This manuscript was published in Critical Care Medicine and currently in the 94th %tile of all articles in similar age in terms of impact. For patients with known ARDS, where knowledge of the plateau pressure and tidal volume is central towards reducing lung injury and improving survival, these data are presented less than 50% of the time. We performed additional recordings to increase this N with the findings being consistent and highlight the importance of restructuring both data gathering and communication of ventilator findings on rounds. The importance of this being magnified in current COVID-19 pandemic. *In toto*, these findings demonstrated, for the first time, the spectrum, significance and frequency of data communication errors on rounds, and the abysmally low frequency at which they are acknowledged in real time. They highlight the critical role the means of data extraction plays in the decision to communicate said findings and forms the basis for data in subsequent aims.

Specific Aim #1B. "Conduct a formal, local and national needs assessment for information communication during IP ICU rounds. Locally, we deployed the survey across all ICU providers at OHSU. We had 375 responses (60% response rate), with representation from pharmacy, nursing, physicians and respiratory therapy. The results suggest that for any given data domain (labs, respiratory data, vitals, medications and consultant notes) less than 30% of providers feel the data is accurately presented on rounds, regardless of ICU or professional role. This is currently independent of ICU location. Interestingly, the perceived quality of the presented data was dependent on the source of the data, with data derived from the EHR, felt to be more accurate and timely than data derived from verbal signout or at the bedside. We validated our local findings through the dissemination of a similar survey nationally to all North American members of the Society for Critical Care Medicine (SCCM). We had 754 responses (6% response rate) with representation from all professional groups. We have now

completed the Theme analysis of all of the qualitative data with a number of major recurring themes. **1**. Is the importance of time management and the role the EHR plays in both positively and negatively impacting this. **2.** Is the interprofessional nature of rounds and how the types of professional groups present on rounds impacts what data is presented and by whom**. 3.** That effective rounds are limited in part by EHR design and technical issues. **4.** That there is wide variability in communication of information during rounds, both in terms of accuracy and precision. **5**. The data overload has significant negative impact on the efficiency and effectiveness of ICU rounds. **6.** The current rounding structure has resulted in the loss of traditional bedside rounds and **7.** That significant problems exist with the accuracy of presented data on rounds. More importantly, these findings mirror the results observed in our in situ observations in Aim #1A and provide external validation to our hypothesis and concerns.

For Aim #2 "Creating of Controlled Interprofession ICU Rounding Simulation," we succesfully created a series of new simulated EHR charts containing all of the requsite data elements. In order to understand each professional groups' workflow for rounds and EHR use, we initially did a multi-professional simulation, working with each individual professional group separately. In this study, 25 physicians, 29 nurses and 20 pharmacists participated. Individual participants were given verbal and written sign-out and then asked to review a simulated record in our institution's EHR which contained 14 patient safety items. After reviewing the chart, subjects presented the patient and the number of safety items recognized recorded. Forty percent, 30% and 26% of safety issues were recognized by physicians, nurses and pharmacists respectively (p=0.0006) and no item recognized 100% of the time. There was little overlap between the three groups with only 50% of items predicted to be recognized 100% of the time by the team. Differential recognition was associated with marked differences in EHR use, with only 3/152 EHR screens utilized by all three groups and the majority of screens used exclusively only by one group. Through the use of a high-fidelity simulation, we demonstrated that the different members of the interprofessional team are relatively poor at identifying safety issues in our institution's EHR. More importantly, there were significant silos in which an interprofessional team's expertise and workflow may have increased recognition of safety issues in certain domains. This was published in the Journal of Interprofessional Care.

As a take-off from this study, we noticed that eye tracking metrics for nurses and physicians were fundamentally different in terms of fixation/saccade ratio and prediction of gaze metrics with performance. This resulted in a re-review of all physician eye-tracking data from our EHR simulations. We reviewed 93 Physicians (46 female, 47 male) simulations. Two gaze patterns were identifiable: one characterized more so by saccadic ("scanning") eye movements and the other characterized more so by longer fixations ("staring"). Female physicians were more likely to use the scanning pattern; they had a shorter mean fixation duration (P=0.005), traveled more distance per minute of screen time (P=0.03), had more saccades per minute of screen time (P=0.02), and had longer periods of saccadic movement (P=0.03).The average proportion of time spent staring compared to scanning (Gaze Index; GI) across all participants was approximately 3:1. Females were more likely than males to have a GI<3.0 (P=0.003). At the extremes, males were more likely to have a GI>5 while females were more likely to have a GI<1. Differences in navigational strategy had no impact in task performance. These findings suggesting that females and males demonstrate <u>fundamentally different</u> navigational strategies while navigating the EHR. This has potentially significant impacts for usability testing in EHR training and design. Further study is needed to determine if the detected differences in gaze patterns produce meaningful differences in cognitive load while using EHRs. These data were accepted for publication in JMIR Human Factors.

Using the experience for the above studies, we created a novel, first-in-kind, interprofessional ICU rounding simulation. We completed 28 ICU rounding simulations with two separate cases. Twenty-

eight teams recognized 68.6% of safety issues with only 50% teams having the primary diagnosis in their differential. Individually, interns, nurses and pharmacists recognized 30.4%, 15.6% and 19.6% of safety items respectively. However, there was a negative correlation between the intern's performance and the nurse's or the pharmacist's performance within a given team. The wide variance in recognition of data resulted in wide variance in orders. Overall, there were 21.8 orders requested and 21.6 orders placed per case resulting in 3.38 order entry mistakes/case. Between the two cases there were 142 distinct orders place with 41% being unique to a specific team and only 3.5% placed by all teams. Further, the order-writer actually navigates to even more screens in the EHR during the presentation than any professional group does during their preparation for rounds. This highlights not only the importance of including the order writer in our ICU rounds learning laboratory, but identified a new latent safety risk in the current rounding structure. This manuscript was accepted in Critical Care Medicine and is currently ranked in the 87%tile of all manuscripts of similar age. Finally, we have further begun to map the errors observed with actual rounds to the content of the simulated cases. Errors eligible for inclusion were those that either occurred at high frequency or had high safety potential. Many of these such as the calcium, respiratory rate, ventilator data and non-physician consultant notes have been included already. Importantly not only do we observe the same gaps in data presentation between actual and simulated rounds (establishing concept and face validity for the simulations), but by ensuring that these data elements are integral to recognition of safety events, we established that their omissions is as much of a systems issues as opposed to a cognitive one, and that the likelihood of these elements being presented and recognized in actual rounds is likely independent of the actual patient.

For Aim #3, "Develop and test standardized methods for Interprofessional data collection and presentation for ICU Rounds" we modified existing rounding artifacts to identify issues with data omission on actual rounds. This was driven by the significant, and serious, safety issues identified by the failure to reliably verbalize and recognize critical ventilator data. The standardized ICU note template was introduced during the "standard roll-out" phase. All trainees were instructed to use the new template during their ICU orientation. Template use was reinforced 2-months later for interns during their boot-camp week with a dedicated EHR simulation exercise focused on use of the new template in the context of reviewing a high-fidelity ICU chart and presenting for ICU rounds. Daily ICU rounds were audio-recorded and copies of all rounding artifacts collected to measure uptake of the new template and assess the relationship between its use and data miscommunication on rounds. We obtained data from 137 presentations. Paper artifacts were used for 94% of presentations with 90% generated from the EHR. Immediately following the standard roll-out, 71% of all presentations used the new template, however this decreased to 47% 2-months later. For interns, their adoption rate for using the template at least once increased from 75% to 100% after simulation training. Consequently, template use remained high (76% of presentations) for interns, whereas the percentage of presentations using the template fell (67% vs. 18%; $p<0.001$) for those who did not receive simulation training. Finally, 91% of audited data domains were included in artifacts created with the new template. Conversely, artifacts created by other means contained only 51% of data domains. When we utilized a data pull of ALL progress notes generated over the year, we found consistently that use of the artifact was higher amongst those who received simulation training. However, we also discovered that the use of progress notes for rounding in general was inversely related to ICU census, with de-adoption during periods of high strain. Unfortunately, similar to our findings from Aim #2, the mere inclusion of data onto a rounding artifact through passive importation of data had little impact on verbalization, suggesting the need for further training on the nature of the data elements and highlighting the need for alternative models. While these findings do not support this strategy of note modification to improve communication, they did highlight the value of simulation based training for improving and standardizing EHR training.

Based on this, we continued EHR onboarding during Intern bootcamps. After two additional years of onboarding (N=72), participants found the activity useful and enjoyable immediately and after six months. Intervention interns used more individual screens than prior studies (18 vs 20, p=0.008) but the total number of screens used were the same (35 vs 38, p=NS). Significantly more participants in the intervention group used the ten most common screens (73% vs 45%, p=0.001). Intervention interns used high-yield screens more often and low-yield screens less often than historical controls which persistent on self-report six months later suggesting this form of training not only modifies behavior but standardizes EHR use. These data were published in JMIR Medical Education. Based on these results, we are now integrating EHR based simulation training for ALL new interns at OHSU across all specialties with the goal of deploying to all employees in 2021.

Further, we completed construction of the final prototype of the novel mobile computer to facilitate the RDAD model of rounding. The prototype rounding computer contains three workstations (attending, presenter, order entry), each workstation has two monitors: one for the specific workstation, the other being a shared display of one of the three workstations. One workstation is equipped with a master switch determining which of the three workstations' screens is the shared view. Once created, we performed simulated rounds with seven teams, using a previously validated simulated EHR ICU record. All participants performed rounds according to our current script. At the conclusion, we employed a standard interview script to gain feedback on design and all participants completed a SUS score. Interviews were recorded and analyzed with InViVo. Overall, the mean SUS was 77.3. From qualitative analysis, benefits of the system include overall ease of use, visualization of order entry, better ability to follow thought processes, avoidance of errors and improved opportunities for teaching. Cons include the location of the shared display monitor, need for standardized set of EHR screens to use and potential for prolonging rounding presentations. Recommendations were taken and incorporated to create a survey to assess ideal EHR screens for use during rounds as well as further refinement of the ergonomics. We have since repeated rounds with an additional eight teams, including incorporation of eye tracking. We found that rounds could be efficiently and effectively completed with the novel computer and with the rounding script. Further, we found that both screens are used by the attending, with an average of 100 ocular transitions with the primary screen used 75% of the time. This validates the concept of the dual monitors. While final testing was postponed due to COVID, we will be continuing these studies post the grant. Further, a provisional patent was submitted for the rounding computer with outcome of this pending. In conclusion, we have demonstrated the feasibility to create a mobile rounding computer which supports both an individual's unique role on rounds while facilitating synchronous viewing of real-time data for shared decision making.

In summary, our results establish the critical role the EHR plays both in effective data gathering and thus clinical decision making. Because of variable and ineffective use of the EHR, all professional groups have significant blindspots in data gathering, which are non-overlapping, resulting in serious safety gaps. Of concern, the data elements which are omitted are dependent on the nature of the element, not the significance of the element, meaning certain elements are always omitted, regardless of their importance to the case. We were able to get external validation of our findings based on user perception across the U.S. and then validate the observed errors in a structured manner using a novel high fidelity simulation of Interprofessional ICU rounds. These simulations recapitulated the *in situ* observations, providing a testbed for testing system change and, more importantly, highlighted the impact this has on patient safety, with each team, having a different set of data collection errors resulting in completely different plans by each team. In essence, the variability in care for these simulated patients is tightly linked to the variance in recognition and collection of data by each individual team member. Finally, the simulations uncovered a new safety lesson, specifically the role of the order writer. Finally, our work highlights the importance of the mode of data collection for effective cognitive

processing. The mere automation of data importation into notes and rounding templates failed to improve verbalization or recognition of data, suggesting that data acquisition must be an active process. Likely, the future of rounds and optimal solution will rely on the elimination of the intermediate step of full data gathering, and the use of real time, simultaneous reviewing of data by all members of the Interprofessional team to facilitate distributive cognition and shared decision making. Doing so will require both new hardware solutions as well as a defined script of how to visualize data to allow for a standard approach which spans across providers and teams.

6. List of Publications and Products:

Sakata KK, Stephenson LS, Gorsuch A, Mulanax RA, Bierman J, McGrath K, Mohan V. **Gold JA**. Professional Differences in Electronic Health Records Use and Recognition of Safety Issues in Critically Ill Patients. *Journal of interprofessional care*. 2016; 30:636-42. 10.1080/13561820.2016.1193479 – already in publication database

Artis KA, Dyer EA, Mohan V, **Gold JA**. Accuracy of lab data communication on intensive care unit daily rounds using an electronic health record. *Crit Care Med* 2017; 45(2):179-186.- will add to pub db

Arthurs BJ, Mohan V, Mcgrath K, Scholl G, **Gold JA**. Impact of passive laboratory alerts on navigating electronic health records in intensive care simulations. SAGE Open Special Issue on Informatics. 2018 Apr-Jun:1-10. will add to pub db

Bordley J, Sakata KK, McGrath K, Scholl G, Bierman J, Ngyuen L, Mulanax A, Mohan V, **Gold JA**. Use of a Novel, Electronic Health Record Centered, Interprofessional Intensive Care Unit Rounding Simulation to Understand Latent Safety Issues. Crit Care Med 2018; 46:1570-1576. doi: 10.1097/CCM.0000000000003302 – already in publication database

Artis KA, Bordley J, Mohan V, **Gold JA.** Data Omissions by Physician Trainees on Intensive Care Unit Rounds. Crit Care Med 2019; 47: 403-9. doi: 10.1097/CCM.0000000000003557. – already in publication database

Miller ME, Scholl G, Corby S, Mohan V, **Gold JA**. The Impact of EHR based simulation during Intern Boot Camp on EHR utilization. JMIR Med Ed; 2021 7:1-10. doi: 10.2196/25828. will add to pub db

Seifer DR, McGrath K, Scholl G, Mohan V, **Gold JA**. Sex Differences in Electronic Health Record Navigation Strategies: A Secondary Data Analysis. In Press. JMIR HF 2021. will add to pub db

Provisional Patent for *Computer on Wheels Apparatus for better Inter-professional Communication*, which was reported in iEdison on 7/25/2019 and was assigned IR # 6297007-19-0036