1 Title: Using Technology to Improve Medication Safety at Brigham and Women’s Hospital

2 Background knowledge: Adverse Drug Events (ADE) are a common occurrence for hospitalized patients, and many of them are caused by human errors and are by definition preventable. These medication errors (MEs) can occur at any point during the medication use process, including ordering by physicians, transcription by unit clerks, dispensing by pharmacists, administration by nurses, and monitoring by the care team. A closed loop medication process is the optimal solution to preventing medication errors and the goal of Brigham and Women’s Hospital (BWH), a 777-bed teaching affiliate of Harvard Medical School and founding member of Partners Health Care Enterprise. BWH is a highly acclaimed hospital for both medical quality and use of information technology. This year BWH became a HIMSS Stage 6 hospital, an honor shared by less than 2 percent of all HIMSS members.

3 Local problem: In the early 1990s work conducted at Brigham and Women’s Hospital highlighted the frequency and severity of medication errors. In the ADE Prevention Study, Bates et al. found an overall adverse drug event (ADE) rate of 6.5% per 100 admissions. Of these ADEs, 28% were judged preventable.1 Dedication to patient safety and technology innovation lead BWH on a 15 year journey to improve medication safety through a series of health care technology initiatives.

4 Intended improvements: To address all potential sources of medication errors (MEs), multiple technologies must be implemented to address every stage of the medication use process, including prescribing, medication order verification, dispensing, transcribing, administering and monitoring drug therapy. BWH has significantly reduced medication errors by implementing a Computerized Prescriber Order Entry (CPOE), Pharmacy Order Verification and Drug Dispensing Process, Administration Electronic Medication Administration Record (eMAR) Administration Smart Pumps, and Adverse Drug Event Monitor.

5 Planning the intervention: All of these projects began with a multi-disciplinary team of nurses, physician, pharmacist and laboratory and information system personnel collaborating on the requirements and design of the new systems and ended with super users, clinical subject matter experts, ensuring the successful implementation of the systems. In each of these projects, the teams decided to pursue internal development as products on the market at the time did not fit the functional needs of the clinicians.

6 HIT Dimensions Utilized: Over the course of the last 15 years BWH has implemented the following systems to improve medication safety and reduce medical errors and adverse drug events:

A) Computerized Order Entry (CPOE)
Ordering is a key step in the medication process. At BWH a multidisciplinary team collaborated to design the CPOE application and its associated decision support. The first goal of this team was to understand the current workflow within each department. Once this task was completed, the team refocused its efforts on designing a system that could be integrated into current practice and minimize process changes. This meant automating current workflow even when in breach of previously un-enforced policy. This decision was made due to a focus on the user acceptance. When a workflow was not in agreement with current policy, it was documented and resolved after user acceptance.

The initial CPOE system required that medication orders include a number of fields, including drug name, dose, route, frequency, and indications for PRN orders. Prior work had demonstrated that many orders were missing one or more of these key fields. Decision support during the initial implementation contained limited drug-drug, drug-allergy, and drug-lab alerts.
B) Medication Reconciliation

Data collected by BWH pharmacists during discharge counseling revealed inadequacies in the documentation of preadmission and discharge medication. Nearly 50% of patients had one or more discrepancies between preadmission regimens and discharge medications. Within BWH this finding validated the need for the Joint Commission’s National Patient Safety Goal to improve medication reconciliation across the continuum of care. BWH opted to build a Medication Reconciliation process.

At BWH when a patient is admitted, the admitting physician can print out a copy of medications that the patient may be taking. The physician then verifies this list during the patient interview, and documents the final list (known as the pre-admission medication list or PAML) electronically. For each medication, a planned action on admission) is also selected to complete the physician portion of the reconciliation process. Once the PAML is complete, pharmacists are notified to verify the accuracy and appropriateness of the PAML and planned actions on admission. The information contained within PAML is available to physicians, pharmacists, and nurses throughout the patient’s admission, especially during times of transfer, handoffs, and discharge. At the time of patient discharge, discharging providers are required to evaluate the inpatient regimen, compare it to the PAML, and determine which pre-admission medications should or should not be continued. The PAML is automatically included in discharge summary documentation. Finally, patient counseling is the last step in the MedRec process to ensure patients and their families understand how their discharge medications differ from pre-admission medications. About 18 months after the electronic PAML system was implemented, functionality to transfer data from the PAML system into the CPOE system as an admission medication order was activated. Benefits of the creation of inpatient medication orders from the PAML saves clinician time and reduces unintentional reconciliation errors when entering medication orders.

C) Pharmacy Order Verification and Drug Dispensing Process

While technologies aimed at improving prescribing such as CPOE and medication reconciliation are important steps to a closed loop medication management system, another critical step involves technologies designed to improve the verification, dispensing, and administration of medications. BWH developed a robust pharmacy information system, equipped with clinical decision support, and bar-code verification technology. This system links the CPOE application to automated dispensing devices at the point of care and interfaces to an electronic medication administration record (eMAR) to further promote medication safety. BWH also implemented a drug storage and retrieval system (carousel) using bar code scanning to restock the automated dispensing machines (ADMs). Pharmacy technicians scan the individual medication to verify the correct item is dispensed before the carousel allows the next item to be picked.

A key component of this project included a complete re-design of the inpatient pharmacy information system. In the new system clinical pharmacists use wireless laptop computers to review patient medication profiles in real time as medication orders are entered in the CPOE system. Pharmacists access pertinent lab information, and past medical history and document medication interventions. The reviewed medication profiles are electronically linked to unit based ADMs. The application incorporates bar code scanning technology to verify correct dispensing, preparation and delivery of medications. The software requires a pharmacy technician to prepare medications using bar code technology and verifies the correct medication, strength, and route are filled to match the dispensing package. Each patient specific medication is visually verified by the pharmacist and then scanned to document the time the medication leaves the pharmacy for delivery. Medications are then scanned for positive delivery to the patient care unit.

D) Administration Electronic Medication Administration Record (eMAR)

The combination of barcode verification technology with an electronic medication administration record (eMAR) was implemented to further reduce administration errors. The eMAR system electronically receives patient profile information from the pharmacy system. At the bedside, barcode/eMAR allows for real-time confirmation of patient identification, medication, dose, and time of administration by automatically checking
the scanned medications against the patient’s eMAR profile. Together, barcode scanning in the pharmacy and barcode/eMAR systems on the inpatient units have the potential to improve medication safety by reducing post-ordering medication errors.

To ensure the successful implementation of this system, a multidisciplinary team met weekly for more than two years to select hardware for the eMAR/barcoding conversion and provide feedback on decisions regarding software enhancements. Rollout of eMAR was completed over several months through a staggered approach. During the rollout nurse super users along with an information systems analyst were available in patient care areas. During the rollout, issues were tracked and enhancements to the application were created daily by the information system staff to resolve any problems that were discovered. At the end of two weeks on every nursing unit the nurse super user completed a 26-item checklist with each user to validate competency prior to transferring support to the BWH Help Desk provided 24/7 coverage for support. This training and implementation strategy was very labor intensive, but hospital leadership considered it essential in order to ensure successful implementation.

E) **Smart IV Pumps**

Including smart pumps in a closed-loop point-of-care medication administration system can further improve medication safety. The goal is to provide seamless digital pathway from CPOE to the patient vein. It has been well documented that intravenous infusion pump errors are a leading cause of life-threatening ADE’s. BWH implemented smart pump technology to decrease risk associated with IV infusions. The first step required development of a drug library. The drug library is designed in accordance with institution specific infusion guidelines. BWH used drug administration guidelines (DAGs), IV dilution guide, and IV push list to develop the library. These guidelines provide a standardized list of drug admixtures and standardized dosing units for all drugs in the library. BWH implemented smart pump technology throughout the facility to avoid confusion regarding use of the hardware, software, and associated disposable products. IV admixture concentrations, dosing units, drug nomenclature, and the procedure for administering medications in the drug library are standardized and compatible with all elements of the closed-loop point-of-care medication management system and institutional resources and reference texts.

F) **Adverse Drug Event Monitor**

Computer based monitoring for potential ADEs improves medication safety. At BWH, a computer based monitor passively evaluates patient specific clinical laboratory data and physician orders using defined logic, or rules, to identify potential ADEs. The system generates a daily roster of patients who are at high risk for a potential ADE. The clinical pharmacists use this list to make clinical recommendations.

8 **Outcomes:** At BWH, we were able to establish a strong partnership with researchers who are interested in understanding the impact of IT systems on patient safety and quality. As such, many of the seminal studies in clinical informatics have been done at BWH. These are the highlights of key results:

- Serious medication errors fell 55% after CPOE implementation
- A study of bar code technology on dispensing errors demonstrated that the rate of target dispensing errors fell by 85%
- Transcription errors were eliminated after the implementation of bar code/eMAR
- Serious medication administration errors fell by 52% after the implementation of barcode/eMAR.
- Adverse Drug Event Monitor demonstrated a 15% increase in total interventions by pharmacy staff on behalf of high risk patients over a 3 year period.

9 **Barriers Encountered:** The most significant barrier faced by BWH was that when this journey started there were no vendor systems and BWH had to build many of the systems themselves. Physician resistance at the early stages of CPOE implementation was significant, and was overcome by a combination of attention to workflow, responsiveness to users’ suggestion, and strong leadership. A barrier currently faced is the extensive resources needed to support a complex closed-loop medication use system.
10 Challenges Faced: Diligence must be practiced when using HIT. For example:

- Following the roll-out of eMAR, continuous quality surveillance has demonstrated some potential new sources of errors. These have required resources to enhance the system and ongoing resources to train and support clinicians.
- ADM’s have their limitations. Care must be taken during ADM set-up and design to ensure that look-alike, sound-alike medications are not stored in the same bins. Staff workarounds may prevent these systems from functioning as designed. Pharmacists and nurses can override the patient safety features thereby defeating its purpose. Management of the emergent patient situations requires that the nurse’ have the ability to override the cabinets safety features. Therefore, attempts to limit the scope and quantity of drugs that are available via override are utilized at BWH. Close monitoring of the use of the override list by a drug safety group is necessary to insure its appropriate use. Another limitation is that nurses may remove the incorrect medication from a drawer with multiple medication bins. In order to avoid picking the wrong drug from the cabinet more current designs alert the user with an auditory alarm if the wrong bin opens for the drug procurement. Finally, the ADM’s must be refilled when medication levels fall below par values and thus are subject to restocking errors. The use of barcode scanning during the restocking process helps to decrease restock errors.
- Despite safety features, errors may still occur when these smart pumps act as stand alone devices or if the system is set up so nurse can bypass the drug libraries. Similarly, nurses may still select the wrong drug to infuse or program the dose within dosing parameters that is not the dose ordered for the patient.

11 Summary: see conclusions

12 Interpretation: see conclusions

13 Conclusions: Medication errors are a common yet preventable cause of adverse events in the hospital setting. Over the course of 15 years, BWH has successfully built out a roadmap for addressing medication errors committed at the ordering, transcribing, dispensing, administration, and monitoring stages. In doing so, not only has BWH built an integrated closed-loop medication system that has greatly improved safety, it has also set the standard for how IT can improve patient safety by demonstrating its value to the rest of the world. While we encountered numerous challenges on the medication safety roadmap, our experience shows that success is possible through steady progress towards a vision, support through leadership, and close collaboration between all clinical disciplines and IT professionals.

14 Financial Considerations: The systems described above are developed and implemented with internal funds at BWH and Partners Healthcare, of which BWH is a founding member. Besides improving patient safety, since 1993, the CPOE system at BWH resulted in a net savings of $23.8 million ($3.2 million annualized). In addition, our pharmacy barcoding system results in a net benefit during 5 years of 3.2 million through medication error avoidance.

Acknowledgement
This case study is based on a Joint Commission Resources publication authored by Brigham and Women’s Hospital clinicians: Karen Fiumara, Pharm.D., Medication Safety Officer; Thomas Moniz, Pharm.D., Informatics Research Fellow Division of General Medicine and Primary Care; William W. Churchill, M.S., R.Ph. Executive Director of Pharmacy Services; Anne Bane, R.N., M.S.N. Nurse Manager, Clinical Systems Innovations Center for Nursing Excellence; Carol J. Luppi, R.N. Nurse Educator, Clinical Systems Innovations Center for Nursing Excellence; David W. Bates, M.D., M.Sc. Chief of Division of General Medicine; Tejal K. Gandhi, M.D., M.P.H. Director of Patient Safety.

References